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FIELD EVALUATION OF SAMPLING AND ANALYSIS FOR ORGANIC POLLUTANTS IN INDOOR AIR

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FIELD EVALUATION OF SAMPLING AND ANALYSIS FOR ORGANIC POLLUTANTS IN INDOOR AIR

by

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The objectives of this study were to determine the feasibility of the use of newly developed indoor air samplers in residential indoor air sampling and to evaluate methodology for characterization of the concentrations of polynuclear aromatic hydrocarbons (PAH), PAH derivatives, and nicotine in residential air. Residential air sampling was conducted in Columbus, Ohio during the winter of 1986/87. The residences were selected on the basis of these characteristics: electric/gas heating system, electric/gas cooking appliances, and amount of cigarette smoking in the home. The PAH derivatives were found at much lower levels than their parent PAH. Higher average indoor levels of all but three target compounds were found compared to outdoor levels. The higher outdoor levels of these three compounds (naphthalene dicarboxylic acid anhydride, pyrene dicarboxylic acid anhydride, and 2-nitrofluoranthene) are probably due to atmospheric transformation. Cigarette smoking was identified as the most significant contributor to indoor levels of PAH and PAH derivatives. Homes with gas heating systems appeared to have higher pollutant levels compared to homes with electric heating systems. However, homes with electric cooking applicances were associated with higher pollutant levels than homes with gas applicances, but the true effects of heating and cooking systems cannot be accurately known because of the small sample sizes and the lack of statistical significance for most pollutant differences.

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FOREWORD

Measurement and monitoring research efforts are designated to anticipate environmental problems, to support regulatory actions by developing an indepth understanding of the nature and process that impact health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina, has responsibility for assessment of environmental monitoring technology and systems, implementation of agency-wide quality assurance programs for air pollution measurement systems, and supplying technical support to other groups in the Agency including the Office of Air and Radiation, the Office of Toxic Substances, and the Office of Solid Waste.

The determination of human exposure to toxic organic compounds is an area of increasing significance to EPA. The field evaluation of sampling and analysis for organic pollutants in indoor air provides an important step toward measurement of, and understanding the extent of, human exposure to these organic pollutants.

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ABSTRACT

The objectives of this study were to determine the feasibility of the use of newly developed indoor air samplers in residential indoor air sampling and to evaluate methodology for characterization of the concentrations of polynuclear aromatic hydrocarbons (PAH), PAH derivatives, and nicotine in residential air.

Residential air sampling was conducted in Columbus, Ohio during the winter of 1986/87. The residences were selected on the basis of these characteristics: electric/gas heating system, electric/gas cooking appliances, and amount of cigarette smoking in the home. The indoor air sampler was equipped with a quartz fiber filter to collect particles followed by XAD-4 resin to trap vapors. A modified EPA medium volume sampler with an identical sampling module was used for outdoor air sampling. Eight homes were sampled; two homes were sampled twice. The indoor air was sampled in the kitchen and the living room over consecutive 8-hr periods. Each outdoor sample was a single 16-hr sample taken simultaneously with the indoor samples.

The levels of PAH detected in outdoor and indoor air samples ranged from 4000 ng/m^3 (naphthalene) to less than 0.1 ng/m^3 (cyclopenta[c,d]-pyrene). The PAH derivatives were found at much lower levels than their parent PAH. Higher average indoor levels of all but three target compounds were found compared to outdoor levels. The higher outdoor levels of these three compounds (naphthalene dicarboxylic acid anhydride, pyrene dicarboxylic acid anhydride, and 2-nitrofluoranthene) are probably due to atmospheric transformation. Cigarette smoking was identified as the most significant contributor to indoor levels of PAH and PAH derivatives. Homes with gas heating systems appeared to have higher pollutant levels compared to homes with electric heating systems. However, homes with electric cooking appliances were associated with higher pollutant levels than homes with gas appliances, but the true effects of heating and cooking systems cannot be accurately known because of the small sample sizes and the lack of statistical significance for most pollutant differences.

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SECTION 1

INTRODUCTION

Recently many research and monitoring efforts have focused on assessing and improving the quality of air. Several studies (1-4) have demonstrated that some polynuclear aromatic hydrocarbons (PAH) and nitrated PAH (NO_2-PAH) found in ambient and indoor air are potent carcinogens, mutagens, or both. There is an increasing concern over human exposure to these compounds in indoor air from the home, workplace, and school because we spend more than 80 percent of our time indoors.

Generally, the sampling methodology used for indoor air sampling has not been fully established. The existing sampling devices (5,6) used in outdoor ambient air sampling are not suitable for indoor sampling applications because of size, lack of portability, and noise. In a pilot residential indoor air study (7), the sampler pumping unit was located outside the house in an insulated housing to minimize the noise level. Depending upon the structure of each house sampled, there were different modifications made to allow the tube connecting the sampling module to the pumping unit to pass through an open window. This sampling device significantly added to the sampling costs and to the levels of inconvenience experienced by the residents of the sampled house. Therefore we have developed a prototype indoor air sampler that is quiet, transportable and relatively unobtrusive(8). This prototype device can be operated at a flow rate (8 cfm) sufficient to collect enough particulate-bound and vapor phase organic compounds over a period of eight hours for chemical analysis and microbioassay analyses.

To determine the feasibility and advantages of using this newly-developed prototype air sampler in residential sampling, a pilot field study was conducted in eight homes in Columbus, Ohio during the winter of 1986/1987. The objectives of this study were to determine the effectiveness of the prototype sampler in collecting residential air samples and to evaluate methodology for characterization of the concentrations of nicotine, polynuclear aromatic hydrocarbon (PAH) and PAH derivatives in residential air. An investigation of the correlations among levels of PAH, nicotine, and numbers of cigarettes smoked was performed. The correlations between three potential PAH markers phenanthrene, pyrene, and fluoranthene and other PAH were also investigated. This study consisted of the following subtasks:

1. Developing a study design for the field study,
2. Performing the field study in the winter of 1986/1987 according to the study design,
3. Conducting chemical analyses of the collected samples and preparing samples for microbioassay analyses,
4. Conducting statistical analyses of the collected data.

SECTION 2

CONCLUSIONS

From this pilot field study, we concluded that the newly developed indoor samplers are quiet, transportable, and acceptable for residential indoor air sampling. The results of the current study were, in general, consistent with the results from the previous pilot study using a different sampling method.

The results of the statistical analyses revealed that cigarette smoking was the most significant contributor to PAH and most PAH derivatives in indoor air. The homes with gas heating systems appeared to have higher PAH and other pollutant concentrations in indoor air, but the effect was not as important as the effect of smoking. The use of electric stoves appeared to result in higher indoor pollutant levels compared to the use of gas stoves. However, the true effect of an electric cooking system is not well known due to the small sample sizes and the lack of statistical significance of observed differences. In addition, further investigation of the data revealed that most of the electric appliance measurements were taken using Sampler C, while the gas appliance measurements were primarily taken using Sampler B. Sampler bias could be responsible for this difference. Comparisons of the effect of sampling locations revealed that the concentrations of the majority of the PAH and PAH derivatives were higher in the living room than in the kitchen, but the difference was statistically significant for only three of the compounds. Sources of variation not included in the statistical model constituted the largest single source of random variation for most target compounds. Home-to-home variation was second largest for most of the compounds, while day-to-day variation was the smallest.

The statistical analyses showed that there was strong evidence of a correlation among the potential PAH markers (phenanthrene, pyrene and fluoranthene) and the other PAH and PAH derivatives. Phenanthrene and pyrene appeared to be better marker compounds than fluoranthene. It was noted that relatively poor correlations were found among PAH markers and the PAH derivatives naphthalene dicarboxylic acid anhydride, pyrene dicarboxylic acid anhydride, and 2-nitrofluoranthene. The poor correlation may be because these compounds can be formed through secondary emission sources (e.g. atmospheric transformation). The investigation of correlations among a potential marker for cigarette smoking, nicotine, and other pollutants revealed that all correlations except one (naphthalene dicarboxylic acid anhydride) were positive and statistically significant. It was noted that quinoline indoor concentrations correlate very well with nicotine indoor concentrations. Therefore, quinoline can be a marker for the contribution of cigarette smoke to indoor PAH levels.

SECTION 3

RECOMMENDATIONS

The following recommendations are based on the results of this study:

1. A study should be performed to conduct statistical analyses of the data from both pilot studies (this study and the 1984 study(7)) to determine whether the results are consistent and to determine whether both data sets can be pooled together to provide better range-finding estimates of the indoor pollutant levels.

2. A study should be performed to improve the acoustic performance of the outdoor ambient samplers, because the noise levels produced by these units was found to be a source of irritation to the residents and neighbors in this study and would probably not be tolerated if sampling were performed when windows of the houses were open.

3. A pilot field study should be performed in the summertime to evaluate the sampler performance at warmer temperatures and to collect more data to assess the effect of cooking systems on indoor pollutant levels.

4. A small scale study of indoor PAH concentrations should be performed during a period of higher furnace use so that the relationship between amount of furnace use and PAH levels can be determined. In any such study it is important that the amount of furnace use be measured.

5. In the design of future residential air studies, it should not be necessary to sample different locations within the home. Fairly good air mixing occurs in most homes so that pollutant concentrations should be fairly uniform throughout the house. The samples are affected more by the residents' activities during the sampling period. Thus, "living room" samples reported here are likely to primarily reflect the cooking associated with dinner preparation while the "kitchen" samples reflect breakfast and lunch preparation activities. In future studies, the "location" variables should either be replaced by a "period of day" variable or by other variables that more specifically describe the residents activities conducted during sampling.

SECTION 4

EXPERIMENTAL PROCEDURES

STATISTICAL DESIGN FOR THE FIELD STUDY

The statistical design for the field study was concerned with the following issues: experimental factors of interest, design restrictions, statistical model, and experimental design. These four issues are detailed in the following paragraphs.

Experimental Factors

In the previous pilot study (7), it was shown that cigarette smoking and the type of heat source and stove type (gas versus electric) had significant effects on the levels of PAH found in residential air. Because of these previous findings, cigarette smoking, furnace type and stove types were included as factors of interest.

Two levels of the factors of furnace type and stove type were considered: gas and electric. In the previous study, cigarette smoking was considered to be a two-level factor with the levels being smoking and non-smoking. However, the number of cigarettes smoked was collected as ancillary data, and it was found in analyzing these data that PAH levels appeared to increase proportionally with the number of cigarettes smoked. Therefore the actual number of cigarettes smoked during sampling was considered to be the factor of interest in this study.

Another factor of interest is the sampling location. In the previous study, it was shown that the PAH levels in the living room and bedroom were related in the same way and with the same statistical significance to the experimental parameters, although bedroom levels were somewhat lower. Because of this result, the sleeping area was not included as one of the sampling locations. Therefore only three locations: kitchen, living room and outdoors, were sampled.

The final factor of interest in this study was the air exchange rate measured during the sampling period for indoor samples. It was noted that the effect of air exchange was statistically significant for some of the PAH in the previous study. The air exchange rate was again included in this study to control for any significant impact it may have on the levels of the target compounds found in indoor air.

Design Restrictions

Because this study is a pilot study rather than a full-scale field study, the number of samples collected was fairly small. We were only able to collect 35 samples to be analyzed for PAH and mutagenicity. Of these samples, five were field blanks used in the assessment of the quality of the data. The 30 remaining samples were collected at eight sample homes. At each sample home we collected three study samples, one in each of the three sampling locations. The samples taken in the kitchen and living room were taken over consecutive 8-hr periods. Each outdoor sample was a single 16-hr sample taken over the same period when the indoor samples were collected. Two homes were sampled twice so that day-to-day variability within a home could be estimated.

The eight sample homes were selected using a two-stage selection process. First, a group of homeowners was formed of acquaintances and coworkers of the Battelle scientists who designed the study. When it was determined that there were not enough homes from which to choose, an announcement calling for volunteers was made throughout the Battelle Columbus campus. By combining these two groups of volunteers we were able to obtain enough potential homes from which to select the eight sample homes. However, based on this group of sample homes, other restrictions on the study became necessary.

A second restriction which limits the scope of the study concerns the availability of homes with gas cooking appliances and electric heating systems. In the screening of homes, we found no homes having both an electric heating system and gas cooking appliances. Thus, all of the air samples were taken at homes with the other three combinations of types of heating system and cooking appliances (gas-gas, electric-electric, and gas-electric).

Statistical Model

Based on the factors of interest and the restrictions placed upon the study, a statistical model was developed for use in designing the study and in analyzing the data. The model used is

$$C = \mu + HS + ST + L + \beta_1 \cdot CIG + \beta_2 \cdot AER + H + D + E \qquad (1)$$

where

C = the measured concentration for the target compound,
μ = the overall average PAH concentration,
HS = the effect due to the type of heating system,
ST = the effect due to the type of cooking appliances (stove),
L = the effect due to the sampling location within the home,
$\beta_1 \cdot CIG$ = the effect of cigarette smoking on PAH levels,
$\beta_2 \cdot AER$ = the effect of air exchange rate (exchanges/hour) on PAH levels,
H = the effect of sampling a specific home (i.e. variability in PAH levels due to home-to-home differences),
D = the effect of sampling on a specific day (i.e. variability due to day-to-day differences in PAH levels), and
E = the combined effects of any other factors not included in the model.

This model was used for each target compound, but the effects were estimated separately for each of the compounds. This model assumes that the measured level of PAH is the sum of the overall average and the various effects due to the factors included in the model.

Note that our model contains no effects due to interactions among the various factors. Interactions have been excluded because there are not enough samples to estimate all the model parameters required for estimating interaction effects.

Sampling Design

Figure 4.1 presents an overview of the sampling design used in the study. Eight homes were sampled, two of which (Numbers 3 and 8) were sampled twice to allow us to estimate day-to-day variability of PAH levels within a given home. The homes selected were chosen to give the greatest variation in the number of cigarettes smoked. In addition, homes were selected so that nearly equal numbers of samples could be taken from each available combination of type of heating system and type of cooking appliance. At each of the sample homes, air samples were taken in the kitchen, the living room, and outdoors. The actual number of cigarettes smoked as well as the type and location in the house were recorded during each sampling period by the house resident. It was stressed by the field personnel that an actual count, not an estimate, was required. Questionnaires were jointly completed by the field technician and the sampling home resident to provide general characteristics of the residence and actual data about cooking and other activities performed during the sampling period.

The order in which the homes were sampled was randomized to remove potential sources of bias that could result if some systematic order was used. No sampling was done either during or immediately following rain. No sampling was performed while the temperature was above 60 degrees. By not sampling during such periods of time we avoided gross inconsistences due to the cleaning of the air by the rain or due to the shutting off of the heating system due to warm weather.

SAMPLING METHODOLOGY

Sampling Procedure

The sampling plan for the field study was to collect each of two indoor samples of 8-hr duration and one outdoor sample of 16-hr duration. The indoor samples were collected from the kitchen from approximately 0700 to 1500 eastern standard time (EST) and from the living room from 1500 to 2300 (EST). A newly developed prototype indoor air sampler(8) was used for the indoor air sampling and a modified EPA medium volume sampler was used for the outdoor air sampling. The characteristics of the test homes are

	Type of Furnace	
Type of Cooking Appliances	Electric	Gas
Electric	Home 7 (0,0 Cigarettes[a]) Home 3 (6,9 Cigarettes) Home 3 (Replicate, 4,0 Cigarettes)	Home 1 (0,0 Cigarettes) Home 6 (9,12 Cigarettes) Home 5 (11,20 Cigarettes)
Gas		Home 8 (0,0 Cigarettes) Home 8 (Replicate, 0,0 Cigarettes) Home 2 (10,16 Cigarettes) Home 4 (7,15 Cigarettes)

(a) The first number is the number of cigarettes smoked during the 7:00 AM - 3:00 PM sampling period in the kitchen. The second number is the number of cigarettes smoked during the 3:00 PM - 11:00 PM sampling period in the living room.

Figure 4.1 Sampling Design for PAH Study of Effects of Gas Versus Electric Heating and Cooking Appliances and Presence of Cigarette Smokers in the Home

summarized in Table 4.1. The sampled residences were selected from volunteered homes meeting desired characteristics, and the order of sampling was selected in a strictly random fashion except for the first residence, which was that of the principal operator for this work. Certain aspects of the sampling procedure differed from usual field sampling procedures because of the need to sample from occupied residences. The activity logs of each sampled home are given in Appendix A.

Prior to their use, the XAD-4 sorbent beds and 104 mm quartz fiber filters were prepared as described in the analytical section of this report. The sorbent cartridge was wrapped in cleaned aluminum foil to protect it from light and sealed in a screw top jar for transport and storage. The filters were enclosed in glass petri dishes or watch glasses, sealed with Teflon tape for transport and storage. All sample containers were labeled with unique identification codes prior to use.

On the day before the scheduled sampling day, indoor and outdoor samplers were taken to the residence for setup. The outdoor sampler was positioned in the backyard or patio area, 10 to 20 feet from the house, depending upon the site characteristics. The location was visually inspected for, and the resident was asked about, possible local combustion sources which might contribute to the sample collection. The indoor sampler was placed in the kitchen to sample the air containing emissions from cooking. At this time a rough sketch of the sampler placement and an estimate of the residence dimensions were made and the type of furnace, stove, and other potential sources (e.g., auxiliary heaters, attached garage, pilot lights) were verified by the sampler operator.

The samplers were loaded with the XAD cartridge and filter and the identification numbers recorded on the sampling form. The indoor sampler was turned on and the flow rate (8 cfm) checked by the operator using a calibrated orifice and manometer. The flow rate was also measured using a digital voltmeter connected to the sampler flow sensor, and the proper deflection of the sampler recorder was verified. The sampler was then turned off and the calibration orifice removed. The pressure drop reading from the Magnehelic gauge affixed to the outdoor sampler was monitored to insure proper operation of the sampler. The inlets of both the indoor and outdoor samplers were enclosed in plastic bags, and the resident was instructed how to turn on both units, take the flow rate indications, and read the temperature and dewpoint from the Solomat instrument. At the start

TABLE 4.1 SAMPLING CONDITIONS FOR TEST HOMES

Home Code	Sampling Date	Indoor Sampler ID	Heating Type	Stove Type	Number of Cigarettes Smoked[b] Kitchen/Liv. Room
1	3/14	B	gas	electric	0/0
2	3/15	C	gas	gas	10/16
3	3/17	C	electric	electric	6/9
4	3/18	B	gas	gas	7/15
5	3/20	C	gas	electric	11/20
6	3/23	C	gas	electric	9/12
7	3/25	C	electric	electric	0/0
8	3/26	B	gas	gas	0/0
8(2)[a]	3/27	B	gas	gas	0/0
3(2)[a]	4/4	C	electric	electric	4/0

(a) Repeat sampling of the same house.

(b) The first number is the number of cigarettes smoked during the kitchen sampling period; the second number is the number of cigarettes smoked during the living room sampling period.

of sampling the following morning, at approximately 7:00 a.m., the resident removed the plastic bags, turned on the units, took the initial readings and then called the sampling personnel and relayed the initial readings.

At approximately 3:00 p.m. the flow rate readings from both samplers were checked by the operator, prior to turning off the indoor sampler to change the XAD cartridge and filter. (The final flow rate readings from all test homes except the Home 8 kitchen location were 8.0 cfm. The final flow rate reading from the Home 8 kitchen location was 7.9 cfm.) Indoor and outdoor temperature and relative humidity measurements were made at this time. The indoor sampler was relocated, its flow rate checked with the orifice, and, with the orifice removed, the evening sample collection was started and the time noted. The sampling cartridges removed from the indoor sampler were resealed in their containers and the XAD cartridge was refrigerated. At 11:00 p.m., prior to turning off both samplers, the operator made and recorded final flow rates and measured indoor and ambient temperature and relative humidity. All samples were resealed in their containers and the XAD placed in the laboratory refrigerator for storage until analysis. At the end of sampling at a site, the samplers were generally left on site for relocation the following day to the next sampling site. With two indoor-outdoor sampler pairs, a different site could be sampled each day.

Air Exchange Rate Determination

An injection of SF_6 was made in each sampled home, and the first sample was taken after one hour. Three or four clean stopped 50-cc syringes were given to the participant for taking air samples every two hours during the first eight hours. The time at which each air sample was taken was written on a label provided on the syringe.

Air samples as received in labelled 60-cc plastic syringes were stored as received at ambient temperature (ca. 20°C) until analyzed. Prior to each injection, the 1 cc sample loop on a Hewlett-Packard 5790 gas chromatograph (GC) with an electron capture detector was purged with at least 50 cc of ultra-pure hydrocarbon-free air. Gas chromatographic parameters for analyses of sulfur hexafluoride (SF_6) in this study were:

Carrier Gas - Zero nitrogen with scrubber
Sample Flow Rate - 25 cc/min
Column Temperature - 55°C
Columns: Collection - Porapak Q; 1/8 in. O.D.; 7 ft length
Separation - Molecular Sieve 5A; 1/8 in. O.D.; 8 ft length

Ultra-pure air injections were used at the onset of analyses each day to establish background parameters. Every sample injection was analyzed in duplicate. Valve and clean air injections were recorded periodically to check instrument performance and to ensure that no cross contamination of SF_6 was occurring from one injection to another. The air exchange rate measured from each test home is given in Table 4.2.

CHEMICAL ANALYSIS METHODOLOGY

Filter and XAD-4 Resin Cleaning Procedure

The XAD-4 resin was purchased from Supelco. The XAD-4 resin was Soxhlet extracted with methanol for 16 hr, followed by ethyl acetate and then dichloromethane for consecutive 16-hr periods. The clean XAD-4 resin was dried with nitrogen, and was packed in a glass cartridge to a bed depth of 2 in. (9). The mass of XAD-4 resin per cartridge was approximately 100 g. The quartz fiber filters (104 mm, QAST, pallflex) were placed in an oven and heated at 400°C for 16 hr prior to sampling.

Sample Preparation

The filter and XAD-4 resin samples from the same sampling location at the same sampling site were combined and extracted with dichloromethane for 16 hr. The extract was further extracted with ethyl acetate for an additional 8 hr. After extraction, the dichloromethane extract and ethyl acetate extract were combined and concentrated by Kuderna-Danish (K-D) evaporation to a final volume of 1 ml. An aliquot (25µl) of each extract was removed for gravimetric analysis. The residue was accurately weighed (± 1 ng) on a Mettler Model ME30 microbalance, and this weight was used to determine the total extractable organic mass collected on the filter and the

TABLE 4.2 AIR EXCHANGE RATES FOR TEST HOMES

Home Code	Air Exchange Rate, hr^{-1}
1	1.98
2	1.71
3	0.18(a)
4	1.14
5	0.72
6	0.89
7	0.38
8	0.20(b)
8(2)	0.20(b)
3(2)	0.50(a)

(a) Samples for Home 3 were collected during period with no entrance/exits; 3(2) is for the same home, but with several entrance/exits.

(b) The measurements were made on one day, with no entrance/exits during measurement period.

XAD-4 resin. The remaining extract was divided into two equal portions. Portion I was used for chemical analysis and portion II was used for micro bioassay analysis.

Gas Chromatography/Mass Spectrometry Analysis

Positive chemical ionization gas chromatography/mass spectrometry (PCI GC/MS) was used to determine selected PAH, nitrogen heterocyclic compounds and nicotine. Negative chemical ionization (NCI) GC/MS was performed to determine selected nitro-PAH (NO_2-PAH) and oxygenated PAH (OXY-PAH).

A Finnigan 4500 GC/MS was used for the GC/MS analysis. Methane was used as the carrier gas as well as the reagent gas. A bonded-phase fused silica capillary column, Ultra No. 2 crosslinked 5% phenylmethyl silicone, was used as the GC column. The outlet of the GC column was located at the inlet of the MS ionization source. Data acquisition and processing were performed with a Finnigan INCOS Model 2300 data system. The GC and MS operating conditions are listed in Table 4.3.

The standard solutions containing the target compounds (Table 4.4) were analyzed by PCI GC/MS in the multiple ion detection (MID) mode to determine the calibration curves. The internal standard, 9-phenylanthracene, was added to the standard solutions and the sample extracts at constant concentration levels (1.0 ng/μl) prior to analysis. Ion peaks monitored by MS were the protonated molecular ion peaks of the target compounds. The sample extracts were analyzed concurrently with the standard solutions. Identifications of the target compounds in the sample extracts were based on the correct molecular ion and the correct retention times relative to the internal standard, as determined from the standard analyses. The response factor for each target compound relative to the internal standard was calculated from the standard analyses. Quantification of each target compound was based on the following equation:

$$Cx(ng/m^3) = \frac{As \times Cis \times Fv}{Ais \times Rf \times V}$$

where

Cx = Concentration of the target compound found in the air sampled, ng/m^3

TABLE 4.3 GC AND MS OPERATING CONDITIONS

Chromatography	
Column:	HP Ultra No. 2 crosslinked 5% phenyl methyl silicone 50 m x 0.31 mm, 0.17 μm film thickness
Carrier:	methane
Carrier linear flow velocity:	50 cm/sec at 250°C
Injection volume:	1 μl
Injection mode:	splitless (1) or on-column(2)
Temperature Program	
Initial column temperature:	45°C
Initial hold time:	2 min
Program rate:	100°C (5 min) to 320° at 6°C/min(1) or at 10°C/min(2)
Final hold time:	10 min
Mass Spectrometer	
Ionization:	150 ev
Filament emission current:	0.3 ma
Preamplifier:	10^{-8} amp/volt
Electron multiplier gain:	10^{5} gain

(1) Used for the PCI GC/MS method.

(2) Used for the NCI GC/MS method.

TABLE 4.4 TARGET COMPOUNDS DETERMINED FROM THE PCI GC/MS ANALYSIS

Compound	m/z
Naphthalene	128
Acenaphthylene	152
Phenanthrene	178
Anthracene	178
Fluoranthene	202
Pyrene	202
Cyclopenta[c,d]pyrene	226
Benz[a]anthracene	228
Chrysene	228
Benzofluoranthenes	252
Benzo[e]pyrene	252
Benzo[a]pyrene	252
Indeno[1,2,3-c,d]pyrene	276
Benzo[g,h,i]perylene	276
Coronene	300
Quinoline	129
Isoquinoline	129
Nicotine	162

As = Area count of the target compound
Cis = Concentration of the internal standard, 1 ng/μl
Ais = Area count of the internal standard
Rf = Response factor of the target compound
Fv = Total volume of a sample extract, μl
V = Total volume of air sampled, m^3

The standard solutions containing selected NO_2-PAH and OXY-PAH (Table 4.5) were analyzed by NCI GC/MS technique in MID mode. Prior to analysis, the internal standard, D_9-1-nitropyrene, was added to the standard solutions and the sample extracts at 0.1 ng/μl level. The identification and quantification of the target compounds in the sample extracts were performed similarly as described in the PCI GC/MS method except for two compounds, naphthalene-1,8-dicarboxylic acid anhydride and pyrene-3,4-dicarboxylic acid anhydride. Identification of these two compounds was based on the retention times relative to the internal standard from the analyses of the exposed standard solutions of acenaphthylene and cyclopenta[c,d]pyrene. Because the pure standards of these two compounds are not available, the quantification of these compounds was based on the assumption that the response factors of these compounds is 1.

Sample Preparation for Microbioassay

The vials used for microbioassay were placed in a 400°C oven and heated for 16 hr to remove any organic material. The screw caps of these vials were Soxhlet extracted with methanol for 16 hr and dried with a nitrogen gas stream. The sample extracts were diluted with dichloromethane to the extent that 1 ml of each aliquot represented 10 m^3 of outdoor and 2 m^3 of indoor air collected. The dose levels of each sample extract are summarized in Table 4.6. According to the dose levels, aliquots of the diluted extracts were removed to clean sample vials and were evaporated to near dryness under a gentle nitrogen stream. A 2 μl aliquot of dimethyl sulfoxide (DMSO) was added to each sample vial after evaporation. The DMSO sample extracts were mixed with a Vortex mixer and evaporated under nitrogen for an additional five minutes. Then the sample vials were sealed with screw caps and immediately stored under dry ice. The sample extracts were prepared in three batches separated by sampling location and sent to EPA/HERL for

TABLE 4.5 TARGET COMPOUNDS DETERMINED FROM THE NCI GC/MS ANALYSIS

Compound	m/z
9-Fluorenone	180
Naphthalene-1,8-dicarboxylic acid anhydride	198
9-nitroanthracene	223
9-nitrophenanthrene	223
Pyrene carboxaldehyde	230
2/3-nitrofluoranthene	247
1-nitropyrene	247
1,6-dinitropyrene	292
Pyrene-3,4-dicarboxylic acid anhydride	272

TABLE 4.6 DOSE LEVELS OF FILTER AND XAD-2 COMBINED EXTRACT FOR MICROBIOASSAY

Sample(a) Code	Dose Level, m^3/vial	Number of Vials per Each Dose Level
1-K	5,2,1,0.5,0.2,0.1,0.05,0,02	5
1-L	5,2,1,0.5,0.2,0.1,0.05,0.02	5
1-0	10,5,2,1,0.5,0.2,0.1	4(b)
2-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
2-L	5,2,1,0.5,0.2,0.1,0.05,0.02	5
2-0	10,5,2,1,0.5,0.2,0.1	5
3-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
3-L	5,2,1,0.5,0.2,0.1,0.05,0.02	4
3-0	10,5,2,1,0.5,0.2,0.1	5
3(2)-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
3(2)-L	5,2,1,0.5,0.2,0.1,0.05,0.02	5
3(2)-0	10,5,2,1,0.5,0.2,0.1	5
4-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
4-L	5,2,1,0.5,0.2,0.1,0.05,0.02	4
4-0	10,5,2,1,0.5,0.2,0.1	5
5-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
5-L	5,2,1,0.5,0.2,0.1,0.05,0.02	4(b)
5-0	10,5,2,1,0.5,0.2,0.1	5
6-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
6-L	5,2.1,0.5,0.2,0.1,0.05,0.02	4
6-0	10,5,2,1,0.5,0.2,0.1	5
7-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
7-L	5,2,1,0.5,0.2,0.1,0.05,0.02	4
7-0	10,5,2,1,0.5,0.2,0.1	5
8-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
8-L	5,2,1,0.5,0.2,0.1,0.05,0.02	5
8-0	10,5,2,1,0.5,0.2,0.1	5
8(2)-K	5,2,1,0.5,0.2,0.1,0.05,0.02	5
8(2)-L	5,2,1,0.5,0.2,0.1,0.05,0.02	5
8(2)-0	10,5,2,1,0.5,0.2,0.1	5
field blank	normalized 10,5,2,1,0.5,0.2,0.1	5

(a) The number of the sample code denotes the home code; K denotes kitchen location; L denotes the living room location; 0 denotes the outdoors.

(b) Only three replicate vials were prepared for the highest dose level.

SECTION 5

RESULTS AND DISCUSSION

SAMPLER PERFORMANCE

The indoor air sampler was found to operate in a very satisfactory manner throughout the study. The unit pulled a steady flow rate for each of the sampling periods, and was stable from site to site as well. None of the residents voiced any complaints regarding the unit's operation, although some were surprised at the size of the unit. Its relatively large size is a drawback since it does require two people to move it into and out of the transport vehicle or up stairs, but it is not felt that the unit could be built significantly smaller and still achieve the desired quieting of the motor.

One aspect of sampler operation discovered in this work is that the sampler should be flushed with air in a clean environment after operating in a house with heavy smoking. The interior of the sampler accumulates some contaminants from the smoke-laden air, probably after the sampler is turned off and ambient air penetrates into the cabinet through the exhaust duct. It was found that operating the unit in a smoke-free environment for several hours would permit it to be used in the next study site without carry-over of contaminants from smoking.

GRAVIMETRIC ANALYSIS OF THE SAMPLE EXTRACTS

The extractable organic mass data from the sampled homes are summarized in Table 5.1. As shown in Table 5.1, the extractable organic mass concentrations found in indoor air samples ranged from 0.077 mg/m^3 to 0.57 mg/m^3; and the outdoor ambient air concentrations ranged from 0.0091 mg/m^3 to 0.047 mg/m^3. In general, relatively higher levels of organic matter were found in the indoor air samples compared to that from the corresponding

TABLE 5.1 EXTRACTABLE ORGANIC MATERIAL OBTAINED FROM THE XAD-4 AND FILTER COMBINED SAMPLES

House Code	Total Extractable Organic Mass, mg (mg/m^3)(a)		
	Kitchen	Living Room	Outdoor
1	7.2(0.066)	6.7(0.064)	3.5(0.016)
2	18(0.17)	16(0.16)	3.9(0.018)
3	14(0.12)	9.7(0.11)	2.5(0.011)
4	13(0.12)	25(0.28)	2.4(0.012)
5	43(0.40)	60(0.57)	10(0.047)
6	24(0.17)	25(0.28)	4.6(0.019)
7	9.5(0.079)	13(0.15)	5.3(0.024)
8	32(0.29)	13(0.13)	1.9(0.0091)
8(2)	15(0.13)	18(0.17)	2.6(0.012)
3(2)	14(0.13)	7.8(0.077)	2.8(0.013)
field blank(b)	0.03(0.0003)	0.03(0.0003)	0.03(0.0002)

(a) The numbers in the parentheses are expressed as concentrations of extractable organic mass in air sampled, mg/m^3.

(b) For the field blank, 100 m^3 of air was assumed to be sampled in the kitchen and living room and 200 m^3 of air outdoors.

outdoor air samples. The data suggested that cigarette smoking contributes to the higher levels of extractable organic matter found in the indoor air samples. For example, the highest concentrations of organic mass were found at home 5 in the living room location where the highest numbers of cigarettes were smoked during the sampling period. It was noted that the highest extractable organic mass among the outdoor air samples was also from home 5. The field blank data showed that insignificant amounts of organic matter were present in the blank samples. This finding indicated that the contamination from sampling and sample handling are negligible.

GAS CHROMATOGRAPHY/MASS SPECTROMETRY ANALYSIS

The combined XAD-4 and filter samples were analyzed by using PCI GC/MS for the determination of nicotine, quinoline, isoquinoline and PAH and using NCI GC/MS for the determination of NO_2-PAH and OXY-PAH. The GC/MS data are summarized in Table 5.2 through 5.11.

As shown in these tables, the most abundant PAH found in indoor air was naphthalene and the least abundant PAH, in general, was cyclopenta[c,d]-pyrene. In most cases, higher levels of PAH were found in the indoor air samples from the homes occupied by smokers. As expected, very high levels of nicotine were detected in the indoor air samples when cigarettes were smoked during the sampling period. To accurately measure the contents of nicotine in those samples, the sample extracts were diluted by a factor of 10 to 200 and were reanalyzed by PCI GC/MS.

The concentrations of PAH derivatives including NO_2-PAH and OXY-PAH determined from NCI GC/MS analyses were lower than that of their corresponding parent PAH. The levels of OXY-PAH were, in general, relatively higher than the levels of NO_2-PAH. It was noted that the outdoor ambient air concentrations of naphthalene and pyrene dicarboxylic acid anhydrides were higher than those found in the indoor air from most of the sampling sites. From the previous study (10), we know that the reactive PAH, acenaphthylene and cyclopenta[c,d]pyrene partially decompose to naphthalene and pyrene dicarboxylic acid anhydrides during sample storage. Thus, we expected more acenaphthylene and cyclopenta[c,d]pyrene decomposition to naphthalene and pyrene dicarboxylic acid anhydrides in the outdoor ambient air compared to that in the indoor air, since higher ozone

TABLE 5.2 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 1

Compound	Concentration, ng/m^3 Kitchen	Living Room	Outdoor
Naphthalene	550	800	170
Acenaphthylene	12	18	3.1
Phenanthrene	55	71	35
Anthracene	1.8	5.0	0.92
Fluoranthene	7.4	7.6	6.5
Pyrene	4.9	4.6	3.8
Cyclopenta[c,d]pyrene	0.14	0.12	0.90
Benz[a]anthracene	0.39	0.29	0.42
Chrysene	0.86	0.75	1.0
Benzofluoranthenes	1.2	0.74	1.4
Benzo[e]pyrene	0.55	0.49	0.56
Benzo[a]pyrene	0.25	0.28	0.29
Indeno[1,2,3-c,d]pyrene	0.44	0.35	0.46
Benzo[g,h,i]perylene	0.66	0.51	0.60
Coronene	0.44	0.37	0.39
Nicotine	45	170	4.8
Quinoline	8.5	9.4	4.2
Isoquinoline	12	21	14
Fluorenone	4.6	4.6	3.4
Naphthalene-1,8-dicarboxylic acid anhydride	5.0	4.2	8.3
9-Nitroanthracene isomer	0.15	0.20	0.20
9-Nitroanthracene	0.12	0.17	0.084
9-Nitrophenanthrene	0.035	0.031	0.033
Pyrene carboxaldehyde	0.049	0.035	0.051
2-Nitrofluoranthene	0.066	0.041	0.064
1-Nitropyrene	0.039	0.021	0.022
Benz[a]anthracene-7,12-dione	0.20	0.18	0.25
Pyrene-3,4-dicarboxylic acid anhydride	0.33	0.21	0.25

TABLE 5.3 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 2

Compound	Concentration, ng/m^3		
	Kitchen	Living Room	Outdoor
Naphthalene	860	1100	200
Acenaphthylene	23	37	10
Phenanthrene	56	87	29
Anthracene	5.3	11	1.5
Fluoranthene	5.8	8.6	6.0
Pyrene	3.9	5.2	5.1
Cyclopenta[c,d]pyrene	0.34	1.1	0.17
Benz[a]anthracene	0.70	1.4	0.60
Chrysene	1.6	2.6	1.4
Benzofluoranthenes	1.7	2.5	1.7
Benzo[e]pyrene	1.5	3.2	0.69
Benzo[a]pyrene	0.62	1.2	0.31
Indeno[1,2,3-c,d]pyrene	0.63	0.97	0.51
Benzo[g,h,i]perylene	0.84	1.4	0.74
Coronene	0.55	0.60	0.46
Nicotine	6800	15000	7.4
Quinoline	94	240	2.4
Isoquinoline	55	140	5.1
Fluorenone	3.0	10	4.2
Naphthalene-1,8-dicarboxylic acid anhydride	5.0	3.4	11
9-Nitroanthracene isomer	0.38	0.36	0.29
9-Nitroanthracene	0.40	0.36	0.057
9-Nitrophenanthrene	0.040	0.10	0.019
Pyrene carboxaldehyde	0.14	0.30	0.10
2-Nitrofluoranthene	0.038	0.067	0.037
1-Nitropyrene	0.034	0.059	0.020
Benz[a]anthracene-7,12-dione	0.38	0.69	0.31
Pyrene-3,4-dicarboxylic acid anhydride	0.44	0.27	0.54

TABLE 5.4 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 3

Compound	Concentration, ng/m^3		
	Kitchen	Living Room	Outdoor
Naphthalene	1200	1100	110
Acenaphthylene	18	17	0.59
Phenanthrene	94	80	17
Anthracene	5.0	4.6	0.55
Fluoranthene	8.1	6.5	3.0
Pyrene	5.0	4.0	1.9
Cyclopenta[c,d]pyrene	0.20	0.20	0.090
Benz[a]anthracene	0.45	0.33	0.22
Chrysene	1.3	0.94	0.59
Benzofluoranthenes	1.0	0.92	0.64
Benzo[e]pyrene	2.5	1.3	0.28
Benzo[a]pyrene	0.56	0.34	0.20
Indeno[1,2,3-c,d]pyrene	0.35	0.40	0.17
Benzo[g,h,i]perylene	0.50	0.51	0.23
Coronene	0.17	0.33	0.10
Nicotine	2000	1700	7.8
Quinoline	84	76	0.78
Isoquinoline	40	34	4.3
Fluorenone	6.8	7.7	3.4
Naphthalene-1,8-dicarboxylic acid anhydride	2.0	1.7	7.8
9-Nitroanthracene isomer	0.41	0.53	0.18
9-Nitroanthracene	0.11	0.15	0.012
9-Nitrophenanthrene	0.023	0.034	0.003
Pyrene carboxaldehyde	0.062	0.10	0.035
2-Nitrofluoranthene	0.021	0.017	0.042
1-Nitropyrene	0.019	0.021	0.020
Benz[a]anthracene-7,12-dione	0.23	0.27	0.14
Pyrene-3,4-dicarboxylic acid anhydride	0.077	0.081	0.19

TABLE 5.5 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 3 (REPEAT SAMPLING)

Compound	Concentration, ng/m^3		
	Kitchen	Living Room	Outdoor
Naphthalene	1700	1300	130
Acenaphthylene	18	17	4.9
Phenanthrene	80	61	23
Anthracene	2.8	1.7	2.0
Fluoranthene	7.2	5.1	5.1
Pyrene	4.7	3.3	3.9
Cyclopenta[c,d]pyrene	0.23	0.17	0.080
Benz[a]anthracene	0.34	0.17	0.83
Chrysene	0.91	0.48	1.4
Benzofluoranthenes	0.71	0.51	1.5
Benzo[e]pyrene	1.1	0.57	0.64
Benzo[a]pyrene	0.30	0.29	0.22
Indeno[1,2,3-c,d]pyrene	0.34	0.30	0.44
Benzo[g,h,i]perylene	0.71	0.41	0.46
Coronene	0.50	0.25	0.17
Nicotine	1800	700	4.9
Quinoline	120	91	5.5
Isoquinoline	47	36	4.5
Fluorenone	8.4	6.3	2.8
Naphthalene-1,8-dicarboxylic acid anhydride	1.7	1.3	14
9-Nitroanthracene isomer	0.31	0.25	0.24
9-Nitroanthracene	0.043	0.039	0.032
9-Nitrophenanthrene	0.024	0.008	0.039
Pyrene carboxaldehyde	0.11	0.039	0.13
2-Nitrofluoranthene	0.030	0.009	0.021
1-Nitropyrene	0.050	0.026	0.023
Benz[a]anthracene-7,12-dione	0.30	0.12	0.29
Pyrene-3,4-dicarboxylic acid anhydride	0.051	0.036	0.51

TABLE 5.6 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 4

Compound	Concentration, ng/m^3		
	Kitchen	Living Room	Outdoor
Naphthalene	810	1100	210
Acenaphthylene	25	48	4.6
Phenanthrene	170	200	34
Anthracene	7.2	12	0.83
Fluoranthene	18	19	6.4
Pyrene	11	11	4.9
Cyclopenta[c,d]pyrene	0.35	0.87	0.18
Benz[a]anthracene	0.66	1.6	0.83
Chrysene	1.4	3.5	1.6
Benzofluoranthenes	1.2	2.7	2.3
Benzo[e]pyrene	1.1	3.7	0.88
Benzo[a]pyrene	0.60	1.4	0.54
Indeno[1,2,3-c,d]pyrene	0.74	1.0	0.74
Benzo[g,h,i]perylene	1.1	1.6	1.1
Coronene	1.1	0.64	0.59
Nicotine	4500	29000	12
Quinoline	170	480	3.4
Isoquinoline	110	300	11
Fluorenone	16	17	3.9
Naphthalene-1,8-dicarboxylic acid anhydride	4.4	6.8	9.9
9-Nitroanthracene isomer	0.38	0.71	0.15
9-Nitroanthracene	0.12	0.48	0.086
9-Nitrophenanthrene	0.028	0.045	0.027
Pyrene carboxaldehyde	0.060	0.21	0.080
2-Nitrofluoranthene	0.031	0.071	0.077
1-Nitropyrene	0.020	0.063	0.021
Benz[a]anthracene-7,12-dione	0.17	0.59	0.26
Pyrene-3,4-dicarboxylic acid anhydride	0.30	0.24	0.56

TABLE 5.7 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 5

Compound	Concentration, ng/m^3		
	Kitchen	Living Room	Outdoor
Naphthalene	1700	2200	330
Acenaphthylene	63	120	8.9
Phenanthrene	130	210	54
Anthracene	8.0	15	1.6
Fluoranthene	14	23	9.4
Pyrene	11	17	9.4
Cyclopenta[c,d]pyrene	1.3	2.0	0.34
Benz[a]anthracene	1.6	3.4	0.58
Chrysene	3.7	7.2	2.2
Benzofluoranthenes	2.9	5.1	1.4
Benzo[e]pyrene	4.5	10	0.63
Benzo[a]pyrene	1.6	3.3	0.30
Indeno[1,2,3-c,d]pyrene	1.0	1.8	0.43
Benzo[g,h,i]perylene	1.4	2.5	0.81
Coronene	1.4	0.64	0.68
Nicotine	25000	45000	29
Quinoline	640	1100	4.0
Isoquinoline	340	620	12
Fluorenone	33	40	9.2
Naphthalene-1,8-dicarboxylic acid anhydride	6.0	6.2	9.4
9-Nitroanthracene isomer	1.1	0.95	0.51
9-Nitroanthracene	0.25	0.32	0.10
9-Nitrophenanthrene	0.19	0.25	0.014
Pyrene carboxaldehyde	0.34	0.33	0.12
2-Nitrofluoranthene	0.16	0.14	0.075
1-Nitropyrene	0.13	0.12	0.036
Benz[a]anthracene-7,12-dione	0.74	0.84	0.37
Pyrene-3,4-dicarboxylic acid anhydride	0.25	0.17	0.23

TABLE 5.8 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 6

	Concentration, ng/m^3		
Compound	Kitchen	Living Room	Outdoor
Naphthalene	1800	4200	120
Acenaphthylene	41	59	1.1
Phenanthrene	76	110	22
Anthracene	4.0	6.0	0.28
Fluoranthene	7.6	6.4	3.9
Pyrene	5.7	9.5	3.4
Cyclopenta[c,d]pyrene	0.24	0.85	0.12
Benz[a]anthracene	0.35	1.4	0.18
Chrysene	1.1	2.4	0.82
Benzofluoranthenes	0.83	2.0	0.61
Benzo[e]pyrene	0.89	6.5	0.24
Benzo[a]pyrene	0.32	1.4	0.10
Indeno[1,2,3-c,d]pyrene	0.18	1.3	0.16
Benzo[g,h,i]perylene	0.39	1.4	0.20
Coronene	0.19	1.4	0.090
Nicotine	4300	4100	1.9
Quinoline	180	300	2.5
Isoquinoline	89	170	4.9
Fluorenone	11	12	3.8
Naphthalene-1,8-dicarboxylic acid anhydride	4.6	3.6	10
9-Nitroanthracene isomer	0.75	0.91	0.50
9-Nitroanthracene	0.18	0.085	0.029
9-Nitrophenanthrene	0.038	0.092	0.10
Pyrene carboxaldehyde	0.26	0.090	0.035
2-Nitrofluoranthene	0.079	0.042	0.12
1-Nitropyrene	0.059	0.076	0.033
Benz[a]anthracene-7,12-dione	0.50	0.23	0.15
Pyrene-3,4-dicarboxylic acid anhydride	0.079	0.085	0.11

TABLE 5.9 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 7

	Concentration, ng/m^3		
Compound	Kitchen	Living Room	Outdoor
Naphthalene	750	1800	110
Acenaphthylene	11	10	4.6
Phenanthrene	55	59	29
Anthracene	1.5	2.0	0.64
Fluoranthene	6.2	7.2	4.3
Pyrene	3.6	5.6	5.1
Cyclopenta[c,d]pyrene	0.18	0.19	0.19
Benz[a]anthracene	0.25	0.24	0.23
Chrysene	0.58	0.93	1.1
Benzofluoranthenes	0.58	0.78	0.51
Benzo[e]pyrene	0.33	0.68	0.28
Benzo[a]pyrene	0.28	0.31	0.15
Indeno[1,2,3-c,d]pyrene	0.31	0.24	0.18
Benzo[g,h,i]perylene	0.55	0.32	0.27
Coronene	0.66	0.31	0.18
Nicotine	200	24	5.1
Quinoline	28	23	2.5
Isoquinoline	67	35	10
Fluorenone	6.6	7.4	3.7
Naphthalene-1,8-dicarboxylic acid anhydride	1.9	7.2	9.7
9-Nitroanthracene isomer	0.22	0.45	0.57
9-Nitroanthracene	0.049	0.13	0.036
9-Nitrophenanthrene	0.014	0.043	0.027
Pyrene carboxaldehyde	0.021	0.023	0.035
2-Nitrofluoranthene	0.009	0.020	0.041
1-Nitropyrene	0.019	0.83	0.017
Benz[a]anthracene-7,12-dione	0.088	0.23	0.17
Pyrene-3,4-dicarboxylic acid anhydride	0.095	0.059	0.19

TABLE 5.10 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 8

Compound	Concentration, ng/m^3		
	Kitchen	Living Room	Outdoor
Naphthalene	1400	880	150
Acenaphthylene	19	8.9	1.7
Phenanthrene	140	86	28
Anthracene	3.5	0.76	0.46
Fluoranthene	23	12	4.6
Pyrene	14	7.4	2.3
Cyclopenta[c,d]pyrene	0.40	0.29	0.050
Benz[a]anthracene	0.43	1.0	0.14
Chrysene	1.6	1.2	0.36
Benzofluoranthenes	1.5	2.5	0.48
Benzo[e]pyrene	0.88	1.4	0.21
Benzo[a]pyrene	0.31	0.83	0.14
Indeno[1,2,3-c,d]pyrene	0.40	1.0	0.23
Benzo[g,h,i]perylene	0.48	1.1	0.28
Coronene	0.23	0.81	0.26
Nicotine	63	60	14
Quinoline	11	9.1	3.0
Isoquinoline	8.1	16	9.6
Fluorenone	10	6.2	2.9
Naphthalene-1,8-dicarboxylic acid anhydride	4.3	2.4	4.8
9-Nitroanthracene isomer	0.44	0.29	0.26
9-Nitroanthracene	1.3	0.29	0.051
9-Nitrophenanthrene	0.058	0.023	0.018
Pyrene carboxaldehyde	0.028	0.023	0.019
2-Nitrofluoranthene	0.031	0.017	0.027
1-Nitropyrene	0.030	0.021	0.012
Benz[a]anthracene-7,12-dione	0.410	0.32	0.11
Pyrene-3,4-dicarboxylic acid anhydride	0.13	0.11	0.10

TABLE 5.11 TARGET COMPOUND CONCENTRATIONS IN AIR SAMPLED FROM HOME 8 (REPEAT SAMPLING)

	Concentration, ng/m^3		
Compound	Kitchen	Living Room	Outdoor
Naphthalene	1000	1300	180
Acenaphthylene	13	14	3.8
Phenanthrene	100	110	46
Anthracene	3.0	1.7	0.79
Fluoranthene	13	14	7.0
Pyrene	7.4	8.6	3.5
Cyclopenta[c,d]pyrene	0.14	0.13	0.090
Benz[a]anthracene	0.34	0.41	0.20
Chrysene	1.4	2.0	0.51
Benzofluoranthenes	1.6	2.5	0.74
Benzo[e]pyrene	0.71	1.2	0.29
Benzo[a]pyrene	0.49	0.67	0.13
Indeno[1,2,3-c,d]pyrene	0.48	0.70	0.26
Benzo[g,h,i]perylene	0.66	0.74	0.44
Coronene	0.26	0.46	0.32
Nicotine	48	69	9.9
Quinoline	9.0	13	4.6
Isoquinoline	18	19	17
Fluorenone	9.0	9.1	4.5
Naphthalene-1,8-dicarboxylic acid anhydride	3.6	3.0	10
9-Nitroanthracene isomer	0.32	0.31	0.42
9-Nitroanthracene	0.25	0.16	0.060
9-Nitrophenanthrene	0.021	0.020	0.005
Pyrene carboxaldehyde	0.057	0.051	0.035
2-Nitrofluoranthene	0.049	0.036	0.072
1-Nitropyrene	0.029	0.036	0.018
Benz[a]anthracene-7,12-dione	0.43	0.75	0.17
Pyrene-3,4-dicarboxylic acid anhydride	0.21	0.10	0.32

concentrations expected in the outdoor air sampling conditions may cause the decomposition of these reactive PAH.

STATISTICAL ANALYSIS

The data for this pilot study were collected under a variety of experimental conditions. The relationships between the experimental factors and the observed concentration levels can be quite complex and difficult to quantify. To more fully understand these relationships a statistical analysis was conducted. The analysis was based on a statistical model that approximates the relationship between the levels of each target compound and the specific contribution of each experimental factor to these levels. The factors we studied are:

- electric versus gas heating systems
- electric versus gas cooking appliances
- amount of cigarette smoking in the home.

We also investigated the effects of other factors that affect PAH levels in the home. These factors are the air exchange rate of the home and random variations due to home-to-home and day-to-day differences.

The specific objectives of the statistical analysis were:

- to determine which of these factors systematically and significantly contribute to the target compound levels in the homes;
- to obtain range-finding estimates of the magnitudes of the effects of these factors; and
- to obtain range-finding estimates of the effects of the different sources of variation, such as day-to-day and home-to-home differences in levels of the target compounds in the home.

To address these objectives, several types of analyses were performed. First, we generated various summary statistics for the observed PAH concentrations. Means, standard deviations, minimums and maximums were calculated for the different combinations of the experimental factors. Note that many of the means and standard deviations are based on only three observations, and are therefore potentially subject to large estimation errors. The second type of analysis compared indoor concentrations to outdoor concentrations. The third type involved statistical modeling to assess the relationships and relative influences of the different experimental factors on the observed concentrations. The fourth type of analysis investigated correlations of PAH compounds with nicotine and potential PAH marker compounds. We also investigated correlations between levels of parent PAH compounds and their nitro-PAH derivatives.

The following sections describe the results of these statistical analyses. The results are described in detail for several of the most important compounds. The results for all the target compounds are presented in the appendices.

Summary Statistics

Various summaries of the measured concentration levels were prepared to provide an overview of the study results. These summaries serve a number of purposes. First, they provide us a qualitative interpretation of the data. That is, the summaries tell us what are the typical concentration levels, minimums, maximums, and which concentration measurements should be considered unusual or suspicious. Such information is necessary for determining the types of statistical analyses that can be performed with the available data and helps to determine whether certain nonrepresentative data values should be omitted from subsequent analyses. Second, the summary values provide guidance concerning what to expect as reasonable results from the more complex statistical analyses. For example, if the results from the modeling analyses are not as expected, the summary values are reviewed to help determine why the results were different and whether there were any errors in the analysis or in the statistical assumptions used in the analysis. Finally, the summary values help us interpret the results from the more complex statistical analyses. For example, which sample homes and/or sampling conditions are primarily responsible for the results being observed?

Listings of Measured Concentrations of the Target Compounds. The first type of summary results generated were listings of the measured concentrations for each sample home. Table 5.12 presents the observed

TABLE 5.12 MEASURED LEVEL (ng/m^3) OF BENZO[A]PYRENE FOR EACH SAMPLE HOME AND SAMPLING LOCATION

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Benzo(a)pyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.250	0.280	0.290
2	0.820	1.200	0.310
3 DAY 1	0.560	0.340	0.200
3 DAY 2	0.300	0.290	0.220
4	0.600	1.400	0.540
5	1.600	3.300	0.300
6	0.320	1.400	0.100
7	0.280	0.310	0.150
8 DAY 1	0.310	0.830	0.140
8 DAY 2	0.490	0.670	0.130

concentrations of benzo[a]pyrene (BaP) for all the sample homes and sampling locations within each home. The BaP levels ranged from 0.25 to 3.3 ng/m^3 inside the homes, and the outdoor levels ranged from 0.10 to 0.54 ng/m^3. These levels are consistent, in general, with those found during a similar earlier study (7) to investigate levels of PAH in indoor air. The levels were highest for Homes 2, 4, 5, and 6, which are the homes having gas heating systems and the greatest number of cigarettes smoked during the sampling periods.

Observed levels of nicotine and 1-nitropyrene are given in Tables 5.13 and 5.14, respectively. For nicotine, the levels ranged from 24 to 45,000 ng/m^3 in the indoor air, and ranged from 1.9 to 29 ng/m^3 outdoors. The highest levels of nicotine were observed in Homes 2, 4, 5, and 6. As expected, the greatest amounts of cigarette smoking also occurred in these homes during the sampling periods. For 1-nitropyrene, the levels ranged from 0.019 to 0.83 ng/m^3 in the indoor air, and from 0.012 to 0.036 ng/m^3 outdoors. The value 0.83 ng/m^3 appears to be an outlier and thus was omitted from all analyses except the summary statistics and data listings. One would not expect such a high level of 1-nitropyrene to be observed in the living room of Home 7 (electric furnace, electric cooking appliances, and no cigarettes smoked during sampling). The next highest value was 0.13 ng/m^3. The levels were generally highest for Homes 2, 4, 5, and 6, with the levels being higher in the living room where the most cigarettes were smoked. Table 5.15 summarizes the observed ranges by sampling location for all the target compounds investigated in this study.

Appendix B presents the observed concentrations for all the compounds. These tables allow the reader to easily compare concentrations across the different sample homes.

Comparing Pollutant Levels Across Homes Having Different Characteristics. A prime objective of this study is to investigate the effects of the experimental factors on indoor organic pollutant levels. As part of this investigation, we cross-categorized the sample homes by the type of heating system and the type of cooking appliances. We then calculated for each target compound, the mean, standard deviation, minimum, and maximum of the observed concentration for each category of homes and each sampling location. For each category of home, we also calculated the mean number of cigarettes smoked within each sampling location to assess the

TABLE 5.13 MEASURED LEVEL (ng/m^3) OF NICOTINE FOR EACH SAMPLE HOME AND SAMPLING LOCATION

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Nicotine

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	45.000	170.000	4.800
2	6800.000	15000.000	7.400
3 DAY 1	2000.000	1700.000	7.800
3 DAY 2	1800.000	700.000	4.900
4	4500.000	29000.000	12.000
5	25000.000	45000.000	29.000
6	4300.000	4100.000	1.900
7	200.000	24.000	5.100
8 DAY 1	63.000	60.000	14.000
8 DAY 2	48.000	69.000	9.900

TABLE 5.14 MEASURED LEVEL (ng/m^3) OF 1-NITROPYRENE FOR EACH SAMPLE HOME AND SAMPLING LOCATION

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=1-Nitropyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.039	0.021	0.022
2	0.034	0.059	0.020
3 DAY 1	0.019	0.021	0.020
3 DAY 2	0.050	0.026	0.023
4	0.020	0.063	0.021
5	0.130	0.120	0.036
6	0.059	0.076	0.033
7	0.019	0.830	0.017
8 DAY 1	0.030	0.021	0.012
8 DAY 2	0.029	0.036	0.018

TABLE 5.15 OBSERVED RANGES OF CONCENTRATION (ng/m^3) FOR ALL COMPOUNDS AND SAMPLING LOCATIONS

	Kitchen		Living Room		Outdoor	
	Observed Range		Observed Range		Observed Range	
Compound	Low	High	Low	High	Low	High
Naphthalene	550	1800	800	4200	110	330
Acenaphthylene	11.0	63.0	8.9	120.0	0.6	10.0
Phenanthrene	55	170	59	210	17	54
Anthracene	1.5	8.0	0.8	15.0	0.3	2.0
Fluoranthene	5.8	23.0	5.1	23.0	3.0	9.4
Pyrene	3.6	14.0	3.3	17.0	1.9	9.4
Cyclopenta[c,d]pyrene	0.14	1.30	0.12	2.00	0.05	0.34
Benz[a]anthracene	0.25	1.60	0.17	3.40	0.14	0.83
Chrysene	0.58	3.70	0.48	7.20	0.36	2.20
Benzofluoranthenes	0.58	2.90	0.51	5.10	0.48	2.30
Benzo[e]pyrene	0.33	4.50	0.49	10.00	0.21	0.88
Benzo[a]pyrene	0.25	1.60	0.28	3.30	0.10	0.54
Indeno[1,2,3-c,d]pyrene	0.18	1.00	0.24	1.80	0.16	0.74
Benzo[g,h,i]perylene	0.50	1.40	0.32	2.50	0.20	1.10
Coronene	0.17	1.40	0.25	1.40	0.09	0.68
Nicotine	45	25000	24	45000	2	29
Quinoline	8.5	640.0	9.1	1100.0	0.8	5.5
Isoquinoline	8.1	340.0	16.0	620.0	4.3	17.0
Fluorenone	3.0	33.0	4.6	40.0	2.8	9.2
Naphthalene dicarboxylic acid anhydride	1.7	6.0	1.3	6.8	4.8	11.0
9-nitroanthracene isomer	0.15	1.10	0.20	0.95	0.15	0.57
9-nitroanthracene	0.043	1.300	0.039	0.480	0.012	0.100
9-nitrophenanthrene	0.014	0.190	0.008	0.250	0.003	0.039
Pyrene carboxaldehyde	0.021	0.340	0.023	0.330	0.019	0.130
2-nitrofluoranthene	0.009	0.160	0.009	0.140	0.021	0.120
1-nitropyrene	0.019	0.130	0.021	0.120(a)	0.012	0.036
Benz[a]anthracene-7, 12-dione	0.088	0.740	0.120	0.840	0.110	0.370
Pyrene-3, 4-dicarboxylic acid anhydride	0.051	0.440	0.036	0.270	0.100	0.560
Total Extractable Organic Mass	0.066(b)	0.400(b)	0.064(b)	0.570(b)	0.009(b)	0.047(b)

(a) An outlier value of 0.83 ng/m^3 was omitted.

(b) In mg/m^3.

effects of smoking on the indoor pollutant levels. Appendix C presents the results of these calculations for all the target compounds. The tables of summary statistics given in Appendix C are useful for identifying patterns in the data. Comparing means, minimums, and maximums across various categories of homes is a simple method for determining which factors are associated with differences in PAH levels. This information provides insight into interpreting the range-finding data. However, these comparisons are not necessarily rigorous from a statistical perspective and one needs to be cautious in interpreting the summary statistics.

In this section, we discuss the results for several of the more important pollutants of interest. Our discussion for these pollutants will provide guidance to the reader on how the tables in Appendix C should be interpreted.

Table 5.16 presents the mean, standard deviation, minimum, and maximum values of the BaP levels observed within each category of sample home and sampling location. This table allows us to compare BaP levels across homes that differ on one factor but which are the same for the other factor. For example, we can compare gas versus electric heating systems (furnaces) among those homes having electric cooking appliances. For these homes it is apparent that gas furnace homes had higher BaP levels. However, the gas furnace homes also happened to have higher levels of smoking occur during the air sampling. Thus, the effects of the gas furnace and smoking are difficult to separate. Both factors may have contributed to the higher BaP levels. The effects of gas heating systems and smoking are further investigated during the modeling analysis described later in this chapter. From Table 5.16, we can also compare gas versus electric cooking among those homes having gas furnaces. From these comparisons we see that the homes having electric ranges had higher levels than gas homes. However, the electric range homes had higher levels of cigarette smoking, which may have been the real cause of the higher BaP levels. The modeling analysis described later provides a thorough investigation of the true effects of each factor on BaP levels. Note in Table 5.16 that there are no homes having electric furnaces and gas appliances. This type of home is relatively rare, and we were unable to find any such homes for our study. This limits the kinds of comparisons we can make to just the two kinds of comparisons we discussed here.

TABLE 5.16 COMPARISON OF LEVELS OF BENZO[A]PYRENE (ng/m^3) ACROSS HOMES CATEGORIZED BY TYPE OF FURNACE AND TYPE OF COOKING APPLIANCES

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Benzo(a)pyrene

			CIGARETTE(a)	RESPONSE(b)				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.380	0.156	3	0.280	0.560
	Gas	Electric	6.667	0.723	0.760	3	0.250	1.600
		Gas	4.250	0.505	0.142	4	0.310	0.620
Living Room	Electric	Electric	3.000	0.313	0.025	3	0.290	0.340
	Gas	Electric	10.667	1.660	1.527	3	0.280	3.300
		Gas	7.750	1.025	0.334	4	0.670	1.400
Outdoor	Electric	Electric	.	0.190	0.036	3	0.150	0.220
	Gas	Electric	.	0.230	0.113	3	0.100	0.300
		Gas	.	0.280	0.192	4	0.130	0.540

(a) Mean number of cigarettes smoked during the 8-hr sampling period.

(b) Concentration, ng/m^3.

Table 5.17 presents comparisons of 1-nitropyrene levels across different categories of home. Among those homes having electric cooking appliances, the kitchen levels of 1-nitropyrene were higher for those homes having gas heating systems rather than electric heat. On the other hand, the living room levels were higher for the homes having electric heat. Cigarette smoking does not appear to be the cause of this difference since smoking was higher for the gas heat homes in both the kitchen and living room locations. From Table 5.17 we see that among homes having gas heat, the homes having electric cooking appliances had higher levels of 1-nitropyrene in both the kitchen and living room locations. However, the level of smoking was also higher in the electric appliance homes. The specific effects of the type of cooking appliances and the level of cigarette smoking can only be separated through the modeling analysis.

Cigarette smoking clearly appears to be a significant contributor to levels of PAH and other pollutants in indoor air. In our statistical modeling effort, described later in this section, we found smoking to be a statistically significant contributor (at the 0.001 level of significance which implies there is only a 1 out of 1000 probability that there is actually no effect due to smoking) to the indoor levels of nearly every compound we investigated. Figures 5.1 through 5.3 illustrate the observed relationships between the number of cigarettes smoked (during each sampling period) and the corresponding measured indoor levels of BaP, nicotine, and quinoline, respectively. In each figure, we have plotted the measured level of the compound against the number of cigarettes smoked. Each plotted value represents a single eight hour sampling period. The plot includes all sampled homes and both the kitchen and living room sampling locations. Note that for all three of these compounds the indoor air levels do not increase substantially until approximately 10 or more cigarettes are smoked during the sampling period. Thus, it appears that an average rate of one or less cigarettes smoked per hour does not increase the indoor levels beyond the background levels measured during sampling periods where there were no cigarettes smoked. Any increase in smoking rate beyond one cigarette per hour appears to greatly increase the levels of PAH and other compounds in the air. Note that Figure 5.2 and 5.3 exhibited very similar profile. It appears that quinoline can also be a marker for cigarette smoking.

A more detailed, but more complicated analysis which takes into account the synergistic effects of type of furnace, type of cooking appliance,

TABLE 5.17 COMPARISON OF LEVELS OF 1-NITROPYRENE (ng/m^3) ACROSS HOMES CATEGORIZED BY TYPE OF FURNACE AND TYPE OF COOKING APPLIANCES

CONCENTRATIONS - nanograms/cubic meter

COMPOUND 1-Nitropyrene

			CIGARETTE(a)	RESPONSE(b)				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.029	0.018	3	0.019	0.050
	Gas	Electric	6.667	0.076	0.048	3	0.039	0.130
		Gas	4.250	0.028	0.006	4	0.020	0.034
Living Room	Electric	Electric	3.000	0.292	0.466	3	0.021	0.830
	Gas	Electric	10.667	0.072	0.050	3	0.021	0.120
		Gas	7.750	0.045	0.020	4	0.021	0.063
Outdoor	Electric	Electric	.	0.020	0.003	3	0.017	0.023
	Gas	Electric	.	0.030	0.007	3	0.022	0.036
		Gas	.	0.018	0.004	4	0.012	0.021

(a) Mean number of cigarettes smoked during the 8-hr sampling period.

(b) Concentration, ng/m^3.

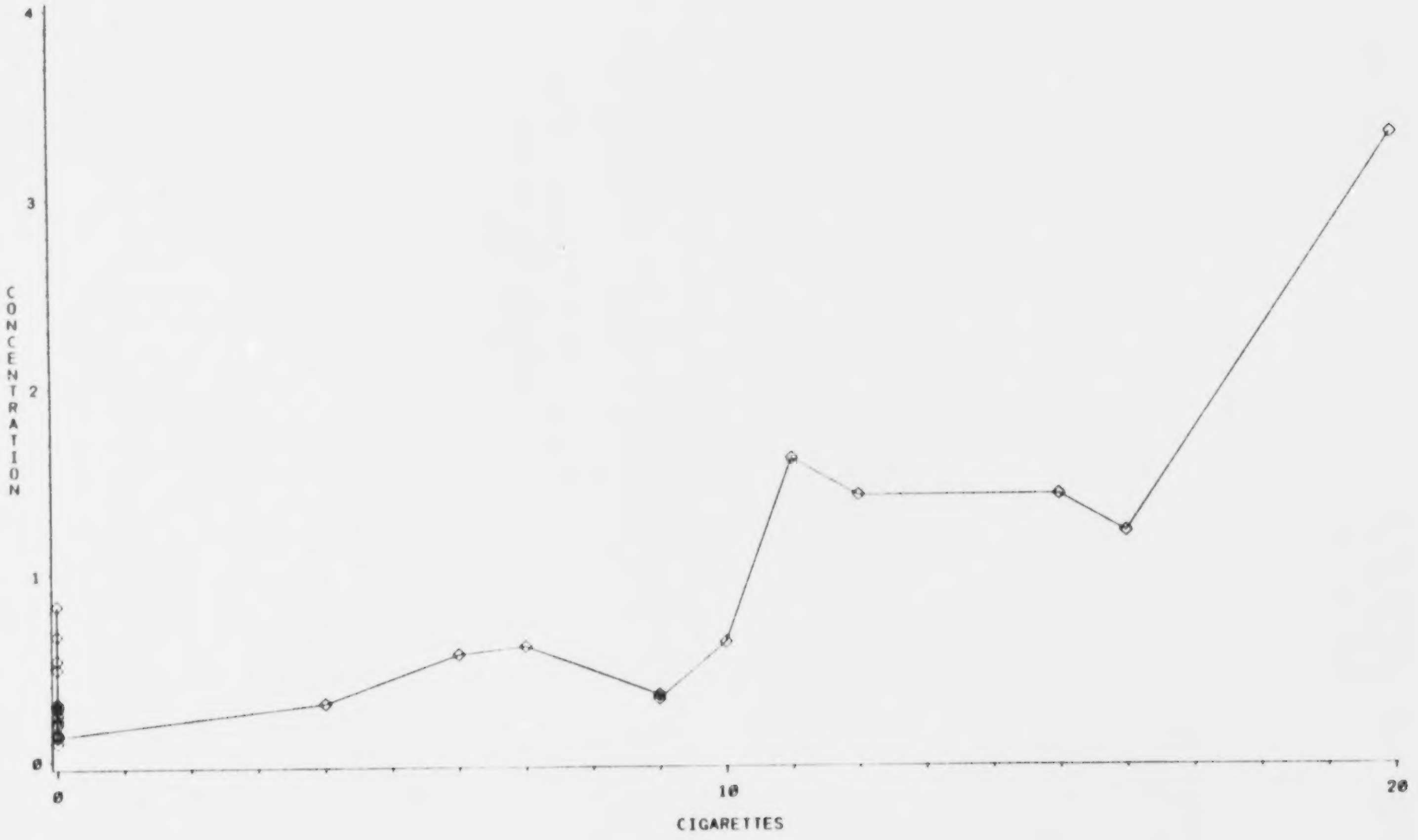

Figure 5.1 Concentration of Benzo[a]pyrene (ng/m^3) Versus Number of Cigarettes Smoked

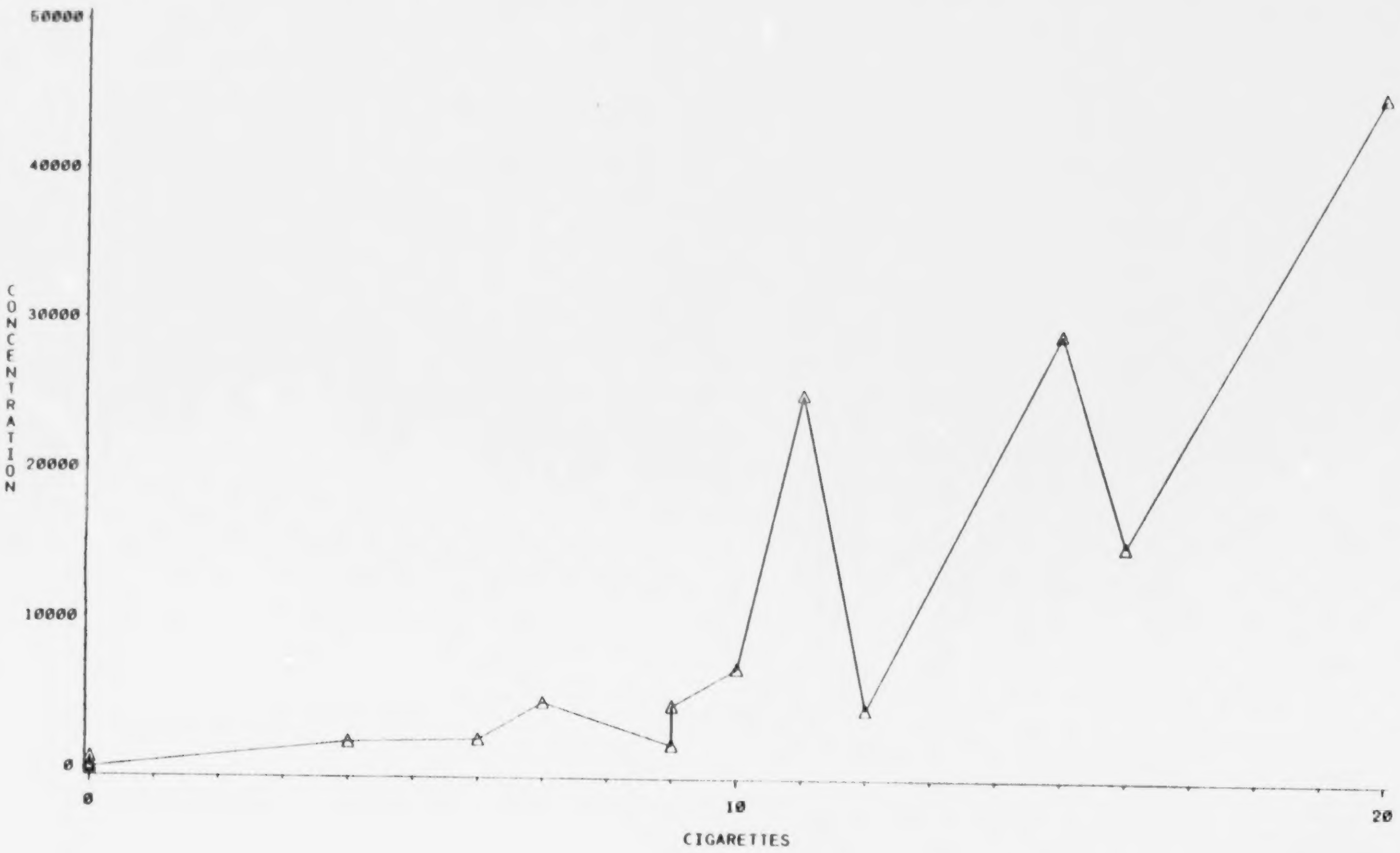

Figure 5.2 Concentration of Nicotine (ng/m^3) Versus Number of Cigarettes Smoked

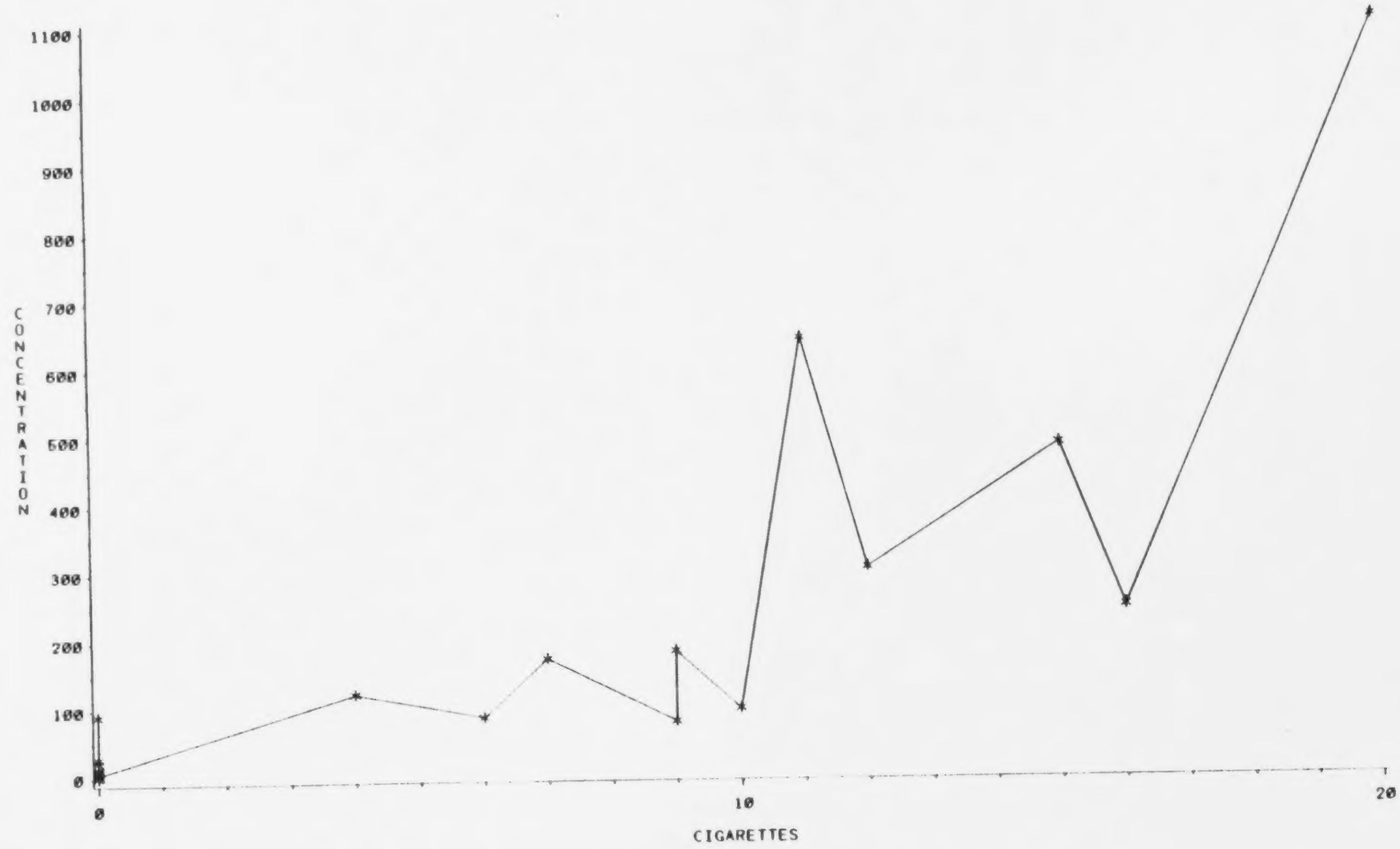

Figure 5.3 Concentration of Quinoline (ng/m^3) Versus Number of Cigarettes Smoked

amount of cigarette smoking, and air exchange rate is given in the section on statistical modeling.

Comparison of Indoor to Outdoor Concentration Levels

Indoor levels of PAH compounds and many other pollutants are suspected to be due primarily to indoor combustion sources such as gas furnaces, gas cooking appliances, and cigarette smoking. Outdoor levels of most of these compounds in residential areas are expected to be relatively low and not significant contributors to indoor levels. In this study we collected data to further investigate this hypothesis. At each sample home we collected a 16-hr outdoor sample to correspond with the two consecutive 8-hr samples taken indoors in the kitchen and living room. Each outdoor concentration was compared to the average of the two corresponding indoor concentrations. We then computed the average indoor to outdoor ratio for each category of homes as defined by the type of heating system and type of cooking appliances. The results are given in Table 5.18. The last column of Table 5.18 provides results on ratios of indoor to outdoor levels as a function of degree of cigarette smoking.

The majority of average ratios in Table 5.18 are greater than one indicating that measured indoor levels were greater than outdoor levels. In many cases the ratios were much greater than one indicating 5 to 10-fold increases in indoor levels over outdoor levels. The indoor levels were as much as 100 to 1000 times greater than outdoor levels for quinoline and nicotine, respectively. Since cigarette smoking is the primary source for these two compounds, we expected to find much higher indoor levels. In fact, the last column of Table 5.18 indicates that the indoor to outdoor ratio of nicotine and quinoline is estimated to increase by a factor of 110 and 10 respectively, for each additional cigarette smoked. Figures 5.4 and 5.5 illustrate the estimated relationship between indoor to outdoor ratio and cigarette smoking for nicotine and quinoline, respectively. In the previous pilot field study (7), relatively lower levels of some nonvolatile PAH, which are mainly particulate-bound PAH were found in the indoor samples compared to outdoor samples. This may be because some of the particulate-bound PAH from outdoor air are adsorbed by building material such as filters, carpets, and walls. However, in the current field study we did not observe the same trend for nonvolatile PAH. Instead higher indoor levels of

TABLE 5-10. RATIOS OF INDOOR TO OUTDOOR LEVELS OF THE TARGET COMPOUNDS

Compound	Gas Furnace Type of Cooking Appliances Electric	 Gas	Electric Furnace Type of Cooking Appliances Electric	Estimated Rate of Change of Indoor to Outdoor Concentration For Each Additional Cigarette Smoked(b)
Naphthalene	9.1	5.7	11.2	0.06
Acenaphthylene	11.9	4.7	4.5	0.82
Phenanthrene	2.9	3.5	3.1	0.09
Anthracene	7.1	6.2	2.8	0.50
Fluoranthene	1.7	2.4	1.6	-0.004(c)
Pyrene	1.6	2.2	1.2	-0.04
Cyclopenta[c,d]pyrene	4.2	3.7	1.6	0.12
Benz[a]anthracene	3.2	1.8	0.7	0.09
Chrysene	2.0	2.0	0.8	0.002
Benzofluoranthenes	1.9	1.6	0.8	-0.005
Benzo[e]pyrene	8.0	3.3	2.7	0.45
Benzo[a]pyrene	5.2	2.7	1.8	0.22
Indeno[1,2,3-c,d]pyrene	2.4	1.7	1.2	0.07
Benzo[g,h,i]perylene	2.1	1.5	1.6	0.05
Coronene	1.9	1.4	2.5	0.07
Nicotine	1101.1	641.3	180.5	109.75
Quinoline	104.6	38.3	24.0	9.99
Isoquinoline	20.3	7.8	6.9	1.89
Fluorenone	3.2	2.6	2.2	0.08
Naphthalene dicarboxylic acid anhydride	0.5	0.5	0.3	0.004
9-nitroanthracene isomer	1.7	1.4	1.1	0.09
9-nitroanthracene	2.6	6.7	3.2	-0.04
9-nitrophenanthrene	5.6	2.5	1.0	0.51
Pyrene carboxaldehyde	2.7	1.9	0.9	0.14
2-nitrofluoranthene	1.0	0.8	0.5	0.05
1-nitropyrene	2.5	2.0	1.3(a)	-0.34
Benz[a]anthracene-7, 12-dione	1.7	2.2	1.0	0.001
Pyrene-3, 4-dicarboxylic acid anhydride	0.9	0.6	0.2	0.002
Total Extractable Organic Mass	9.6(d)	13.9(d)	6.9(d)	0.06(d)

(a) Outlier value of 0.83 ng/m^3 omitted from this calculation.

(b) The rate of change corresponds to the slope of the estimated linear regression line between indoor-to-outdoor ratios of concentration for each sample home versus the number of cigarettes smoked. The indoor concentration was calculated as the average of the kitchen and living room measurements. The number of cigarettes smoked was calculated as the average of the number of cigarettes smoked during the kitchen and living room sampling periods.

(c) The negative slope is only an estimate of the effect of smoking and may be due to other factors not accounted for in this analysis.

(d) In mg/m^3.

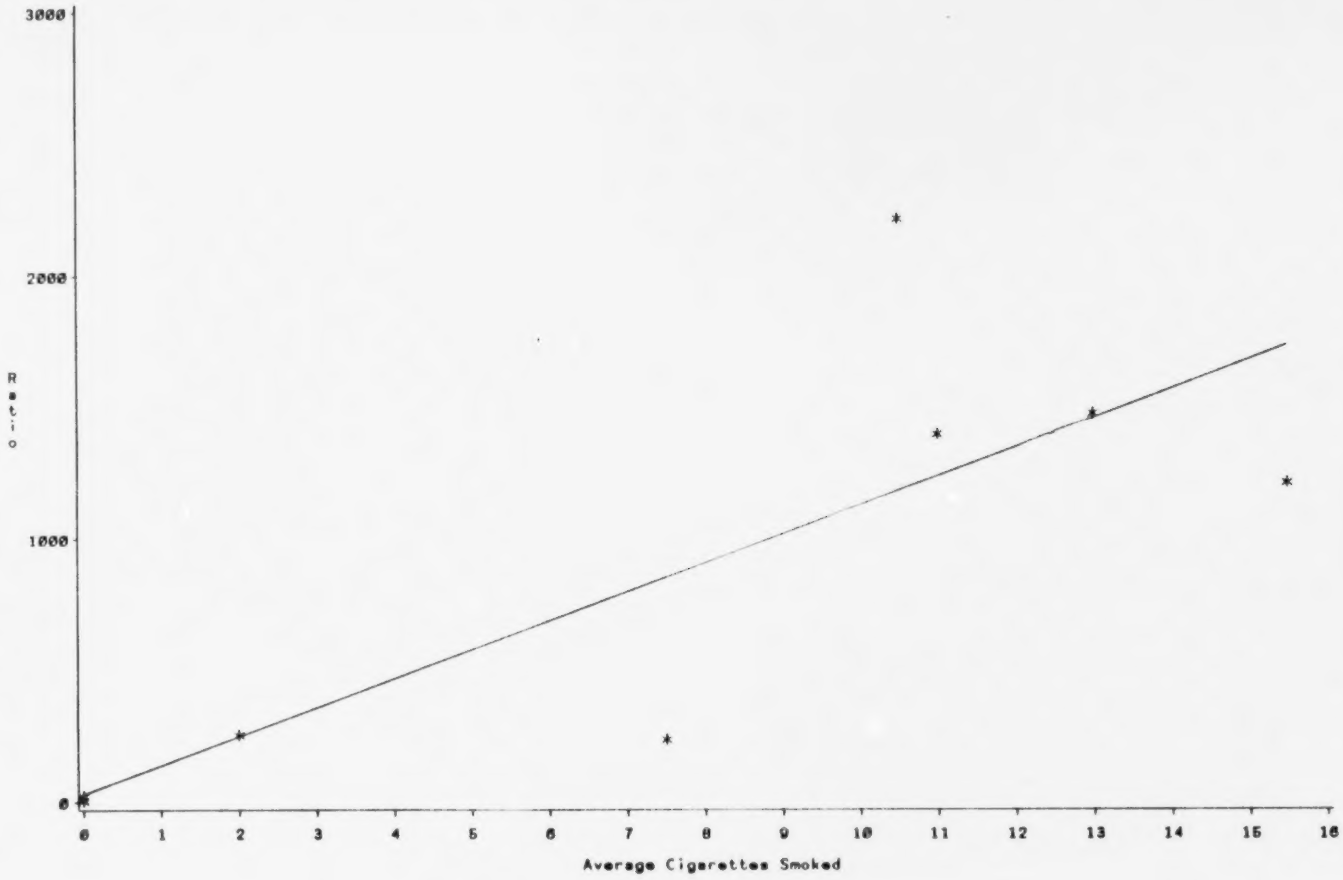

Figure 5.4 Plot of the Ratio of Indoor to Outdoor Nicotine Levels for Each Sample Home Versus the Average Number of Cigarettes Smoked During the Two Indoor Sampling Periods

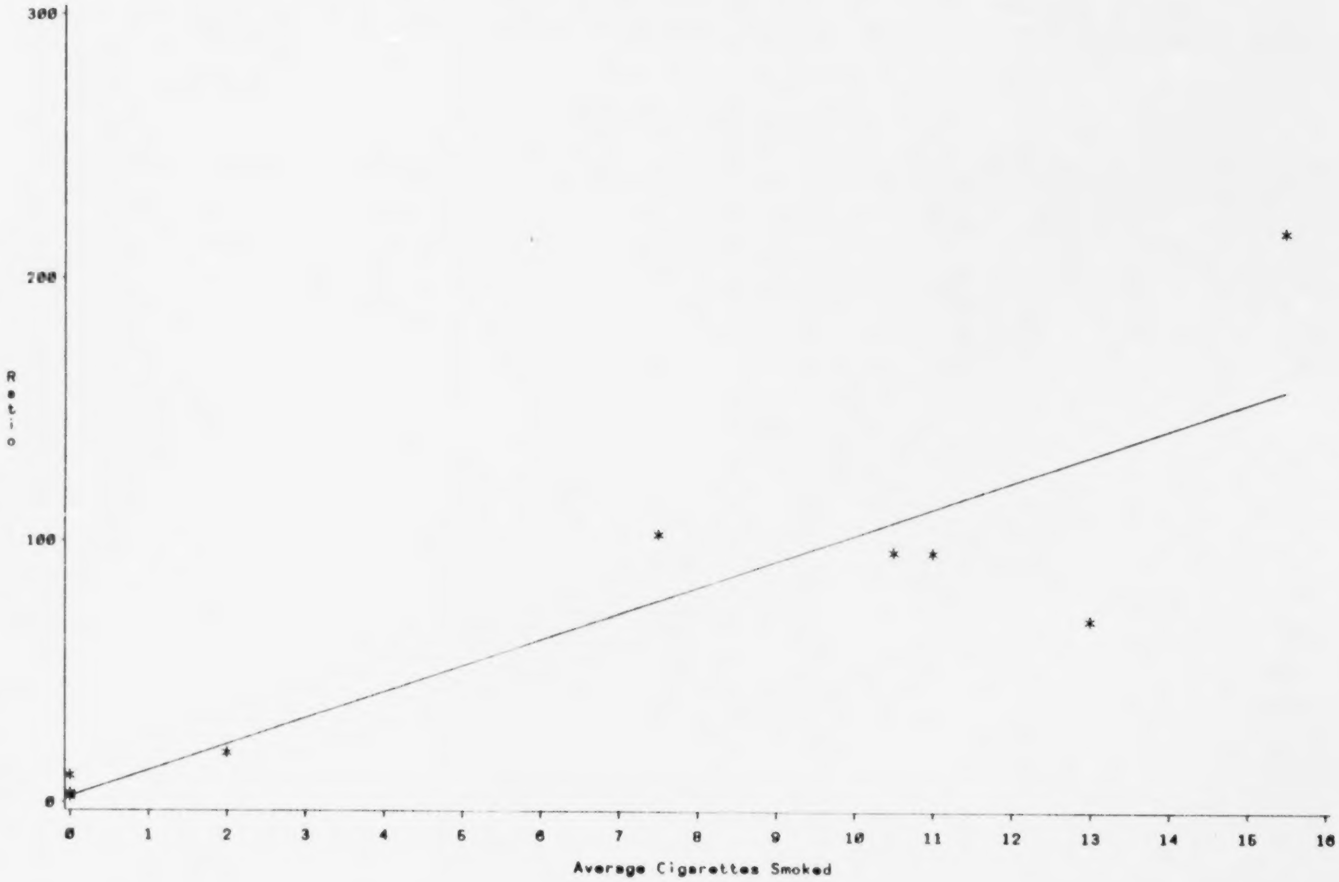

Figure 5.5 Plot of the Ratio of Indoor to Outdoor Quinoline Levels for Each Sample Home Versus the Average Number of Cigarettes Smoked During the Two Indoor Sampling Periods

these nonvolatile PAH were detected. This may be due to the fact that more sampled homes were occupied by smokers in the current study, cigarette smoking is the major source for PAH including nonvolatile PAH, thus higher indoor levels resulted.

Homes having a gas furnace and electric cooking appliances tended to have the highest average of indoor to outdoor ratings. Homes having a gas furnace and gas cooking appliances had the second highest ratios. One would expect the homes having both a gas furnace and gas cooking appliances to have the highest ratios. However, we further investigated the data and found that the gas furnace-electric cooking homes had somewhat more cigarette smoking occur during the sampling periods than did the gas furnace-gas cooking homes. The last column of Table 5.18 indicates that smoking is a significant source of PAH and PAH-derivatives found in indoor air. In fact, the estimated effect of smoking 5 to 15 additional cigarettes in an 8-hr period is enough to account for the differences in the ratios between the gas furnace-electric cooking homes and the gas furnace-gas cooking homes for most of the target compounds. Thus, smoking is likely to be the cause of the higher levels in those homes having electric cooking appliances.

The electric furnace-electric cooking appliance homes clearly had the lowest average ratios of indoor to outdoor levels.

Several PAH derivatives had lower indoor than outdoor levels. This finding suggests that there may be significant outdoor sources for such compounds as naphthalene-1,8-dicarboxylic acid anhydride, 2-nitrofluoranthene, and pyrene-3,4-dicarboxylic acid anhydride. Based on our previous study (10), a few reactive PAH, including acenaphthylene and cyclopenta[c,d]pyrene, partially decomposed to naphthalene-1,8-dicarboxylic acid anhydride and pyrene-3,4-dicarboxylic acid anhydride after storage for 30 days. The increased chemical reactivity of the relatively localized double bond found in acenaphthylene and cyclopenta[c,d]pyrene, apparently makes them susceptible to oxidation to form the corresponding PAH dicarboxylic acid anhydrides. Therefore, we expected more acenaphthylene and cyclopenta[c,d]pyrene decomposition to naphthalene and pyrene dicarboxylic acid anhydrides in the outdoor air compared to that in the indoor air, since higher ozone concentrations were expected in the outdoor air. Other research (11,12) has indicated that 2-nitrofluoranthene present in the ambient outdoor air is mainly from the atmospheric transformation of fluoranthene emitted from combustion sources. This may have caused the higher outdoor than indoor levels of 2-nitrofluoranthene found in our study. Unlike 2-nitrofluoranthene, 1-nitropyrene is a direct emission product, and higher levels of this compound were found in the indoor air samples.

Statistical Modeling

We investigated a number of experimental factors in this study. A key objective was to estimate the contribution of each factor to the overall PAH and PAH derivative levels in the home. For example, key questions included:

- How much do PAH levels differ between homes having gas and those having electric heat? How much do PAH levels differ between homes having gas cooking appliances and those with electric? How much does the PAH level of a home increase with each cigarette smoked?
- How much variability in levels is there among different homes having identical conditions with respect to the experimental factors?
- How much do the levels vary from location to location within the home?
- Within a given home, how much variability in levels is there from day to day?

To answer these questions, a statistical model was fitted to the observed data. The model expresses the approximate relationship between the observed levels of each target compound and the contribution of each experimental variable (factor) under consideration. The objectives of the modeling effort are to determine which factors significantly contribute to the levels and to quantify the magnitude of each contribution.

The methodology and results of the modeling are described in the following sections. Throughout these sections, the quantitative results should be interpreted with the small number of study homes kept in mind. This means that the results should be considered as preliminary, range-finding estimates only, and further studies using a larger number of homes are necessary for precise quantification.

Methodology. Each target compound was addressed separately in the modeling effort; however, the same model and experimental factors were used for all of them.

We also investigated a similar model which expressed log-concentrations as a linear function of the effects of the experimental factors. The results from this model were similar to those found using Equation 1. Since the model in Equation 1 is simpler to use and interpret, we decided to use this model in this range-finding study.

For each compound, the model given in Equation (1) was fitted to the observed data by using the Mixed Model Analysis of Variance program BMDP3V (13). A mixed model analysis of variance was appropriate because the model included a mix of fixed and random effects factors. The concept of fixed versus random effects factors is described below in connection with the parameterization of the model.

For each target compound, we provide a number of results (e.g. Table 5.19) obtained from the model fitting. These results are:

1. An Estimate of Each Coefficient in the Model. The coefficient values are used to make estimates of the contribution of each experimental factor to the overall pollutant level.

2. A Standard Error For Each Coefficient Estimate. The standard error is used to provide a bound on the possible error in the coefficient estimate. The standard error can be used to calculate two specific measures of the precision of our coefficient estimates:

   (a) Percent Relative Standard Error of the Coefficient

   $$\%RSE = \frac{\text{Standard Error of Coefficient}}{\text{Coefficient Estimate}} \times 100\%$$

   (b) 95 Percent Confidence Interval (14) for the Coefficient

   (Lower bound of interval, upper bound of interval) = Coefficient Estimate $\pm$ 2 * (Standard Error of the Coefficient),

3. z-Value and Statistical Significance of the Coefficient. For each coefficient of the model, we calculated a z-value and significance level corresponding to a statistical test of hypotheses for whether the associated experimental factor significantly contributes to the PAH level. If the coefficient estimate is sufficiently different from zero that it is unlikely to be due to random chance, then the experimental factor is considered to be statistically significant at the given significance level.

TABLE 5.19 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR BENZO[A]PYRENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level (a)
HS (Heating System)	0.32	0.25	1.28	.20
ST (Cooking Appliances)	-0.18	0.18	-0.98	.33
β_1 (Cigarettes Smoked)	0.08	0.02	3.85	< .01
L (Location)	0.14	0.07	1.87	.06
β_2 (Air Exchanges Per Hour)	-0.31	0.29	-1.08	.28

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.39
D (Day-to-day variability)	0(b)
E (Variability due to other factors)	0.30

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

The parameterization used to fit the model determines how the coefficient estimates are to be interpreted. In this analysis, a positive value for HS indicates that homes having gas heating systems have estimated concentrations of the target compound above the average (μ) by an amount equal to the estimated value for the coefficient HS. Homes having electric heating systems would then be estimated to have concentrations the same magnitude below the average. Thus, the net effect due to having a gas versus electric heating system would be 2 x HS ng/m^3. ST and L are interpreted similarly. A positive value for ST indicates that homes having gas cooking appliances have estimated concentrations above the average while homes with electric appliances have estimated levels the same magnitude below the average. A negative coefficient for ST indicates that homes with gas cooking appliances have estimated PAH concentration levels below the average while homes with electric appliances are estimated to have average levels the same amount above the average. A positive value for L indicates that the living room has higher estimated concentration levels than the kitchen. A negative value for L indicates that the kitchen has higher estimated levels.

The model component $\beta_1 \cdot$ CIG is called a covariate, and the coefficient β_1 estimates the average change in pollutant level associated with each additional cigarette smoked during the sampling period. For example, the estimated value for β_1 for benzo[a]pyrene (BaP) from Table 5.19 is 0.08 ng/m^3. This implies that we estimate the average BaP level to increase 0.08 ng/m^3 for each additional cigarette smoked during an 8-hr period.

The estimate for the model coefficient β_2 is the estimated rate of change in PAH concentration due to each additional air exchange (AER) per hour. For example, a value of β_1 = -0.31 for AER (see Table 5.19) indicates that the concentration level is estimated to decrease by an amount of 0.31 ng/m^3 for each additional air exchange per hour.

The model components H, D and E are different in nature from the other components. They are called random effects (variance components) as opposed to the others which are fixed effects. For random effects, the interest is not in the effects due to differences in specific homes or days but rather the interest is in characterizing the variabilities among homes or days in general. The coefficient estimates (H,D,E) from the analysis correspond to variance estimates which are estimates of the variability in concentration levels due to differences among homes, days, and other unspecified factors, respectively.

The results of the modeling analysis are given in Appendix D for all the target compounds. The results for benzo[a]pyrene and 1-nitropyrene are presented in this section in order to illustrate how the modeling results should be interpreted.

Benzo[a]pyrene. Table 5.19 presents a summary of the modeling results for benzo[a]pyrene (BaP). The significance levels for the statistical tests of significance indicate that the only statistically significant factors were cigarette smoking (significant at less than the .01 level--less than 1 percent chance that cigarette smoking actually has no effect on BaP levels) and location (significant at the .06 level--approximately a 6 percent chance that there is actually no difference in BaP levels between locations). Although there is not sufficient statistical evidence to say with confidence that the other factors have an influence on BaP levels, the estimated coefficients in Table 5.19 provide our best estimates of the effect of each factor. The estimated effects are as follows:

- Homes having gas heating systems are estimated to have higher BaP levels than homes having electric heating systems by an average of 2 x 0.32 = 0.64 ng/m^3. The previous PAH range finding study (7) obtained a somewhat higher value of 1.48 ng/m^3. However, the 95 percent confidence intervals for the values obtained from the two studies overlap considerably, indicating no inconsistency in results.

- The estimated difference in BaP levels between homes having gas versus electric cooking appliances is 2 x -0.18 = -0.36 ng/m^3, implying that homes having electric appliances are estimated to have higher average BaP levels. This result is contrary to what we expected and we have no obvious reason to explain it.

- BaP levels are estimated to increase an average of 0.08 ng/m^3 for each additional cigarette smoked during an eight hour period. Thus, for example, smoking 10 cigarettes during an eight hour period is estimated to increase the BaP level by 10 x 0.08 = 0.80 ng/m^3.

- The living room is estimated to have higher BaP levels than the kitchen by an average of 2 x 0.14 = 0.28 ng/m^3. The living room also had the highest measured levels in the previous PAH range finding study.

- BaP levels are estimated to change (decrease) by an average of -0.31 ng/m^3 for each additional air exchange per hour.

- The effect due to home-to-home variations is estimated to be as much as two times the square root of the home-to-home variance (see Table 5.19) or 2 x 0.39 = 0.78 ng/m^3. This indicates that homes having identical conditions with respect to the experimental factors can still have BaP levels that differ by as much as ± 0.78 ng/m^3 due to unique characteristics of the home (e.g. pilot lights, number of gas appliances). This estimated home-to-home variability compares well with the value 0.75 ng/m^3 which was obtained in the previous PAH range-finding study.

- The variability due to day-to-day differences are estimated from the observed data to be negligible.

- The variability due to all other uncontrolled factors not addressed by the model is estimated to be as much as ± 2 x 0.30 = ± 0.60 ng/m^3.

The practical significance of the estimated effects of all these experimental factors is best determined by comparing the effects against the typical BaP levels measured in the sample homes. The overall arithmetic average of the BaP measurements (averaged over all the sample homes and indoor sampling locations) is 0.77 ng/m^3. The minimum measured level was 0.25 ng/m^3 and the maximum was 3.30 ng/m^3. Thus, the estimated differences in BaP levels due to the experimental factors are significant when considering typical levels in homes.

1-Nitropyrene. Table 5.20 presents a summary of the modeling results for 1-nitropyrene. The significance levels in the table indicate there were statistically significant differences in 1-nitropyrene levels due to the type of heating system, type of cooking appliances, and the number of cigarettes smoked. All three of these factors were significant at approximately the .01 level, indicating there is only about a 1 percent probability that the observed effects were due merely to random chance. The other factors were not statistically significant. However, regardless of the statistical significance (which is affected by sample sizes and the variability among individual measurements) of the factors, the model coefficients provide the best estimate of the contribution of each factor to the overall 1-nitropyrene levels. The estimated effects are as follows:

- Homes with gas heating systems are estimated to have higher 1-nitropyrene than homes with electric heating systems by an average

TABLE 5.20 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR 1-NITROPYRENE(a)

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level (b)
HS (Heating System)	0.023	0.009	2.62	< .01
ST (Cooking Appliances)	-0.018	0.007	-2.48	.01
β_1 (Cigarettes Smoked)	0.003	0.001	3.77	< .01
L (Location)	-0.003	0.003	-0.86	.39
β_2 (Air Exchanges Per Hour)	-0.017	0.011	-1.57	.12

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0(c)
D (Day-to-day variability)	0
E (Variability due to other factors)	0

(a) These results do not include one measured outlier value of 0.83 ng/m^3.

(b) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(c) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

of 2 x 0.023 = 0.046 ng/m^3. The previous PAH range-finding study also found 1-nitropyrene levels to be higher in gas-heated homes.

- The estimated average difference in 1-nitropyrene levels between homes with gas versus electric cooking appliances is 2 x (-0.018) = -0.036 ng/m^3. This implies that homes having electric appliances are estimated to have higher 1-nitropyrene levels.
- 1-nitropyrene levels are estimated to increase by an average of 0.003 ng/m^3 for each additional cigarette smoked during an eight hour period.
- The estimated average difference between living room and kitchen levels is 2 x (-0.003) = -0.006 ng/m^3, indicating that higher levels were found in the kitchen.
- Each additional air exchange per hour is estimated to reduce the average level of 1-nitropyrene by 0.017 ng/m^3.
- The variabilities due to home-to-home, day-to-day, and other unknown differences were all found to be negligible when compared to the differences due to the other factors (e.g. heating system, cooking appliances) in the model.

The overall arithmetic average of 1-nitropyrene levels measured in the sample homes (including all homes and indoor sampling locations) was 0.046 ng/m^3 with a range of 0.012 to 0.130 ng/m^3. This provides a measure against which to assess the practical significance of the estimated effects of the experimental factors. For example, the estimated difference in 1-nitropyrene levels between gas heated and electrically heated homes is equal to approximately 39 percent of the entire range of levels observed. Thus, the estimated effects of the experimental factors on 1-nitropyrene levels are significant when considering the typical levels found in residential homes.

Summary of Modeling Results for All Compounds. Modeling results for all the target compounds are given in Appendix D. These results indicate which experimental factors were found to have statistically significant effects on the indoor levels of each target compound. The estimated coefficients in each table quantify the estimated effect of each factor on the indoor levels of the corresponding PAH compound. Table 5.21 provides a summary of the effects of the experimental factors for all the compounds.

The first column of the table provides estimated average differences in PAH levels between homes having gas heating systems versus electric heating

TABLE 5.21 ESTIMATED AVERAGE DIFFERENCES IN TARGET COMPOUND LEVELS (NG/M³) DUE TO TYPE OF HEATING SYSTEM, TYPE OF COOKING APPLIANCES, AND AMOUNT OF CIGARETTE SMOKING IN THE HOME

Compound	Gas Versus Electric Furnace[(a)]	Gas Versus Electric Cooking[(b)]	Estimated Change in Average Levels for Each Additional Cigarette Smoked	Estimated Average Difference Between Levels In Living Room Versus Kitchen[(c)]	Overall Arithmetic Average Level of of Compound[(d)]
Naphthalene	839	-933*	35	314	1378
Acenaphthylene	31.3***	-25.6***	3.2***	2.7	29.6
Phenanthrene	28.7	12.6	4.8***	0.1	101.5
Anthracene	0.15	0.50	0.55***	0.39	5.09
Fluoranthene	5.5	2.3	0.4	-1.0	11.0
Pyrene	6.0**	-1.0	0.2*	-0.1	7.4
Cyclopenta(c,d)pyrene	0.35	-0.23	0.07***	0.08	0.47
Benz(a)anthracene	0.61	-0.30	0.10***	0.23	0.79
Chrysene	1.11	-0.59	0.20***	0.25	1.82
Benzofluoranthenes	1.13	-0.11	0.11***	0.43**	1.67
Benzo(e)pyrene	2.43***	1.92***	0.27***	0.81	2.15
Benzo(a)pyrene	0.63	-0.36	0.08***	0.27*	0.77
Ideno(1,2,3-c,d)pyrene	0.48***	-0.08	0.04***	0.23**	0.65
Benzo(g,h,i)perylene	0.41	-0.05	0.06***	0.17	0.89
Coronene	0.33	-0.14	0.02	-0.01	0.57
Nicotine	2994	-2818	1681***	904	7029
Quinoline	215	-204	34***	14	184
Isoquinoline	95	-98	20***	11	109
Fluorenone	10.8	-7.5	0.6***	-0.4	11.4
Naphthalene dicarboxylic acid anhydride	1.46	-0.52	0.11	0.01	3.92
9-Nitroanthracene isomer	0.36***	-0.29***	0.03***	-0.03	0.47
9-Nitroanthracene	0.17	0.20	0.00	-0.07	0.25
9-Nitrophenanthrene	0.062	-0.060	0.005***	0.00	0.056

TABLE 5.21 ESTIMATED AVERAGE DIFFERENCES IN TARGET COMPOUND LEVELS (NG/M^3) DUE TO TYPE OF HEATING SYSTEM, TYPE OF COOKING APPLIANCES, AND AMOUNT OF CIGARETTE SMOKING IN THE HOME
(Continued)

Compound	Gas Versus Electric Furnace[(a)]	Gas Versus Electric Cooking[(b)]	Estimated Change in Average Levels for Each Additional Cigarette Smoked	Estimated Average Difference Between Levels in Living Room Versus Kitchen[(c)]	Overall Arithmetic Average Level of of Compound[(d)]
Pyrene carboxaldehyde	0.06	-0.04	0.01***	-0.03	0.12
2-Nitrofluoranthene	0.062**	-0.042*	0.003**	0.012	0.049
1-Nitropyrene	0.046***	-0.036**	0.003***	-0.006	0.046
Benz(a)anthracene-7,12-dione	0.26*	-0.01	0.02***	0.03	0.38
Pyrene-3,4-dicarboxylic acid anhydride	0.014	0.088**	0.002	-0.064***	0.166
Total Extractable Organic Mass	0.164**	-0.086	0.013***	0	0.183

(a) Each entry in column is the estimated average difference in levels for homes with gas furnaces minus levels in homes with electric furnaces.

(b) Each entry in column is the estimated average difference in levels for homes with gas cooking appliances minus levels in homes with electric appliances.

(c) Each entry in column is the estimated average difference in levels in the living room minus levels in the kitchen.

(d) Each entry is the arithmetic average of the measured concentration levels over all sample homes and sampling locations. The overall arithmetic average level provides a benchmark value against which the effects of gas versus electric heating and cooking and presence of smoking can be compared.

systems. The number of asterisks given with each estimated difference indicates the degree of statistical significance associated with the difference. If no asterisk is given, this indicates there is not sufficient evidence to conclude there is truly a difference in average levels between the two types of heating systems. One asterisk indicates that the observed difference is statistically significant at the 0.10 level, implying there is at most a 10 percent probability that the observed difference is due merely to chance. Two asterisks indicates that the observed difference is statistically significant at the 0.05 level, and three asterisks implies statistical significance at the 0.01 level.

Note from Table 5.21 that the estimated differences in homes with gas versus electric furnaces are positive for all compounds. This indicates that homes having gas heating systems are estimated to have higher average indoor PAH and other pollutant levels than homes with electric heating systems. The practical significance of the heating system differences can be measured by comparing the magnitude of the estimated difference for each compound to the overall arithmetic average of the measured concentration levels (over all sample homes and indoor sampling locations) given in the last column of Table 5.21. These differences generally ranged from 50 to 100 percent of the overall average, indicating the differences due to type of heating system are substantial. The compounds found to have the largest relative estimated differences due to the type of heating system are as follows:

Compound	Difference Due to Furnace Type Expressed As Percent of Overall Average
2-nitrofluoranthene	127
Quinoline	117
Benzo[e]pyrene	113
9-nitrophenanthrene	111
Acenaphthylene	106
1-nitropyrene	100

The differences were statistically significant, however, for only 8 of the 29 target compounds. The lack of statistical significance is due to the small sample sizes and relatively large variations in individual measurements that suggest uncertainty about the true effect of the heating system.

The second column of Table 5.21 presents the estimated differences in target compound levels due to the type of cooking appliances used in the home. For 23 of the target compounds the estimated difference was negative, indicating that electric cooking appliances were associated with higher pollutant levels than gas appliances. The reason for this is unknown; however, only five of the negative differences were statistically significant. As mentioned before, the lack of statistical significance suggests uncertainty about the true effect of the cooking system. The magnitudes of the estimated differences ranged from 3 to 111 percent of the overall average of the measured concentration levels. The compounds whose indoor levels are estimated to be most affected by the type of cooking appliances are as follows:

Compound	Difference Due to Type of Cooking Appliance Expressed As Percent of Overall Average
Quinoline	111
9-nitrophenanthrene	107
Isoquinoline	90
Benzo[e]pyrene	89
Acenaphthylene	86
2-nitrofluoranthene	86

While the magnitudes of the differences associated with the type of cooking appliance were not generally as large as the differences due to the type of heating system there was, nevertheless, a difference between homes with gas versus electric appliances. By examining the residents' activities more carefully, the homes with electric stoves appear to have more cooking activity (frying) than the homes with gas stoves. Further, the majority of measurements for the gas appliance homes were taken using Sampler B while the measurements for the electric appliance homes were primarily taken using Sampler C. Both the differences in cooking activities and samplers may have affected the indoor pollutant levels.

Column 3 of Table 5.21 indicates cigarette smoking is by far the factor which we are most certain affects indoor levels of PAH and other target compounds. PAH levels of all target compounds are estimated to increase with the level of cigarette smoking. In addition, the effect of smoking was statistically significant for 23 of the 29 compounds, with most of the results significant at the 0.01 level. The effect of smoking can be quite significant on indoor pollutant levels. For example, the effect of smoking 10 cigarettes in an 8-hr period produces an estimated increase in nicotine levels by as much as 240 percent of the overall average level observed during the range-finding study. The indoor pollutant levels most affected by smoking 10 cigarettes in an 8-hr period are as follows:

Compound	Difference Due to Cigarette Smoking Expressed As Percent of Overall Average
Nicotine	240
Quinoline	180
Isoquinoline	180
Cyclopenta[c,d]pyrene	150
Benzo[e]pyrene	130

Column 4 of Table 5.21 indicates that the living room had higher estimated average levels than the kitchen for most of the target compounds. This result is consistent with results found in the previous PAH range-finding study (7). However, only a few of these differences were statistically significant and the magnitudes of the differences were generally less than 20 percent of the overall average of the measured concentration levels.

Correlations Among PAH Compounds, Markers, and Derivatives

Phenanthrene, fluoranthene, and pyrene are potential PAH marker compounds whose presence in the air is often considered to be indicative of the presence of other PAH compounds. One objective of this study was to investigate whether strong correlations exist between the levels of the potential PAH marker compounds and the levels of other PAH compounds. If strong correlations exist, the PAH marker compounds can be exploited as a means to more easily monitor for PAH compounds in general.

Table 5.22 presents a matrix of 75 Pearson correlation coefficients obtained by correlating the measured levels of the three potential PAH marker compounds (fluoranthene, pyrene, phenanthrene) with 25 other PAH and

TABLE 5-22. ESTIMATED CORRELATIONS AND STATISTICAL SIGNIFICANCE LEVELS FOR POTENTIAL PAH MARKER COMPOUNDS WITH OTHER PAH AND RELATED COMPOUNDS

	Fluoranthene	Pyrene	Phenanthrene
Naphthalene	0.32340 0.0813	0.50382 0.0045	0.56470 0.0012
Acenaphthylene	0.59632 0.0005	0.73093 0.0001	0.76717 0.0001
Anthracene	0.63254 0.0002	0.65288 0.0001	0.82042 0.0001
Cyclopenta[c,d]pyrene	0.59560 0.0005	0.72673 0.0001	0.71282 0.0001
Benz[a]anthracene	0.58856 0.0006	0.71303 0.0001	0.67895 0.0001
Chrysene	0.67198 0.0001	0.79704 0.0001	0.72437 0.0001
Benzofluoranthenes	0.66033 0.0001	0.73129 0.0001	0.65592 0.0001
Benzo[e]pyrene	0.51813 0.0034	0.68877 0.0001	0.69932 0.0001
Benzo[a]pyrene	0.63013 0.0003	0.73262 0.0001	0.74780 0.0001
Ideno[1,2,3-c,d]pyrene	0.59551 0.0005	0.71469 0.0001	0.70406 0.0001
Benzo[g,h,i]perylene	0.63011 0.0002	0.72736 0.0001	0.74236 0.0001
Coronene	0.33931 0.0666	0.50783 0.0042	0.48963 0.0060
Nicotine	0.60974 0.0003	0.65588 0.0001	0.73203 0.0001
Quinoline	0.58704 0.0007	0.69287 0.0001	0.73975 0.0001
Isoquinoline	0.60503 0.0004	0.70181 0.0001	0.75176 0.0001

TABLE 5-22. ESTIMATED CORRELATIONS AND STATISTICAL SIGNIFICANCE LEVELS FOR POTENTIAL PAH MARKER COMPOUNDS WITH OTHER PAH AND RELATED COMPOUNDS (Continued)

	Fluoranthene	Pyrene	Phenanthrene
Total PAH	0.33933	0.52002	0.58085
	0.0666	0.0032	0.0008
Fluorenone	0.71249	0.80590	0.79638
	0.0001	0.0001	0.0001
Naphthalene dicarboxylic acid anhydride	-0.20636	-0.10126	-0.38847
	0.2739	0.5944	0.0339
9-Nitroanthracene isomer	0.41545	0.62935	0.57635
	0.0224	0.0002	0.0009
9-Nitroanthracene	0.69575	0.58518	0.51585
	0.0001	0.0007	0.0035
9-Nitrophenanthrene	0.53172	0.67502	0.60253
	0.0025	0.0001	0.0004
Pyrene carboxaldehyde	0.36848	0.46143	0.49091
	0.0451	0.0103	0.0059
2-Nitrofluoranthene	0.29663	0.41479	0.27977
	0.1114	0.0227	0.1343
1-Nitropyrene	0.47260	0.64061	0.60972
	0.0096	0.0002	0.0004
Benz[a]anthracene-7, 12-dione	0.64009	0.65681	0.63200
	0.0001	0.0001	0.0002
Pyrene-3,4-dicarboxylic acid anhydride	-0.07956	-0.07896	-0.21305
	0.6760	0.6783	0.2583
Total Extractable Organic Mass	0.75106	0.83407	0.84342
	0.0001	0.0001	0.0001

related compounds, including TOTAL PAHs constructed by adding the concentrations of other PAH compounds. Each correlation is based on comparing the observed level of one compound with the observed level of another compound. We used all the measured concentrations across all eight sample homes and all three sampling locations, kitchen, living room, and outside. Thus, each correlation is based on 30 pairs of measured concentrations.

For each pair of compounds, the top number of each pair of entries in Table 5.22 is the estimated correlation level. Possible correlation levels range between -1 and +1, with a positive number indicating a direct relationship between the two compounds and a negative number indicating an inverse relationship between the compounds. A direct relationship implies that the concentration level of one compound tends to be high when the level of the other compound is high, and tends to be low when the other compound is low. An inverse relationship (negative correlation) implies that one compound tends to be high when the other compound is low and vice versa. Correlations close to ± 1 indicate that the relationship is strong while a correlation near zero indicates there is no strong relationship. The bottom number in the correlation table for each pair of compounds is a statistical measure of the strength of the relationship. The value is the significance level (α-level) of a statistical test of hypothesis that there is zero correlation between the two compounds. Values greater than 0.10 indicate there is at least a 10 percent probability that the observed correlation is due to chance and hence there is no strong evidence of a correlation. Values less than 0.10 tend to imply there is a relationship. The closer the value is to zero, the stronger the evidence is that there is a relationship between the two compounds.

Except for naphthalene-1,8-dicarboxylic acid anhydride and pyrene-3,4-dicarboxylic acid anhydride, all the estimated correlation coefficients with the potential marker compounds in Table 5.22 are positive and statistically significant, indicating there is strong evidence that the levels of the PAH marker compounds are directly related to the levels of the other compounds. Phenanthrene and pyrene appear to be better marker compounds than fluoranthene since their estimated correlations were somewhat higher. As examples of the relationships between PAH compounds and their markers, Figures 5.6 through 5.8 present plots of the measured levels of BaP versus fluoranthene, pyrene, and phenanthrene, respectively. Note that in each

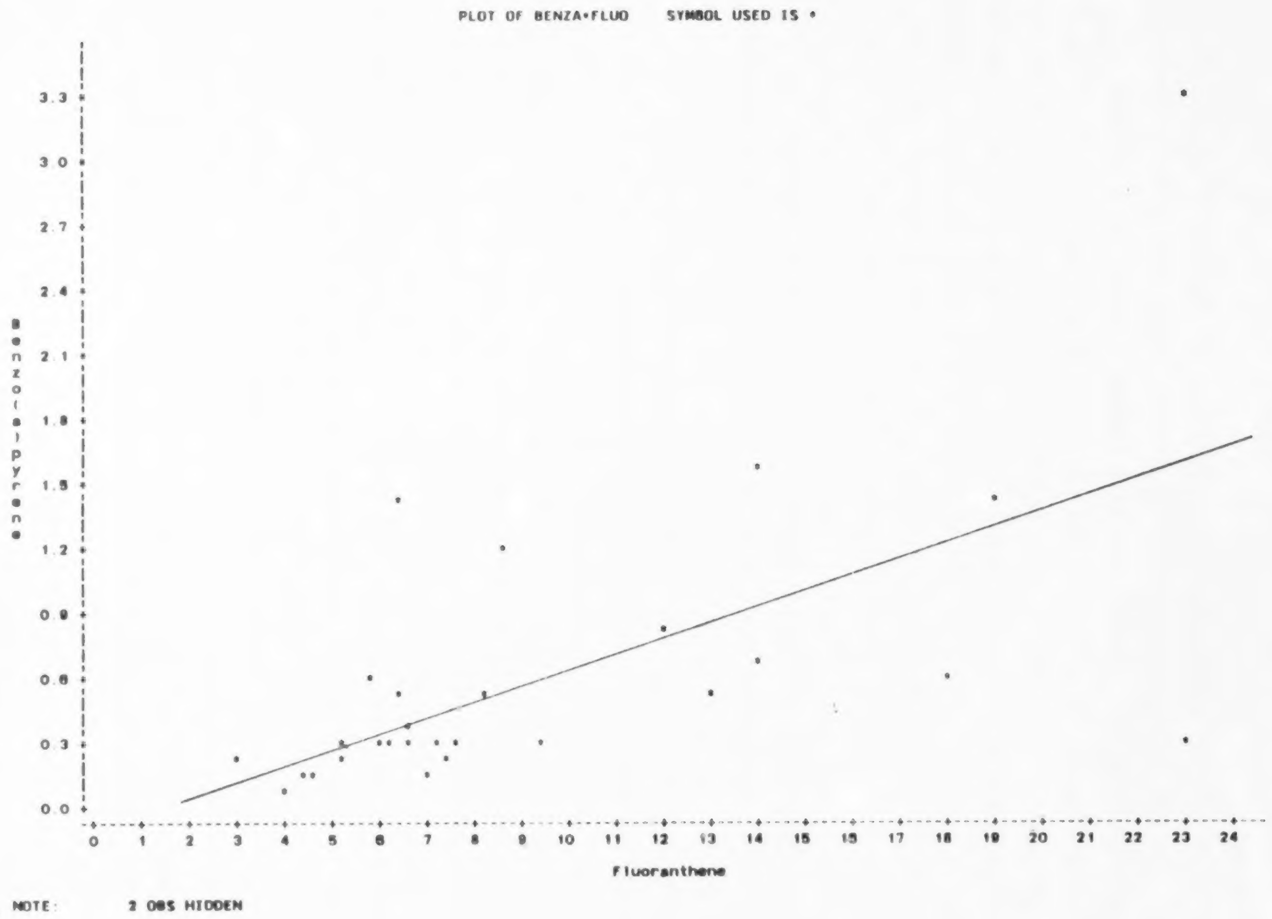

Figure 5.6 Plot of Concentration of Benzo[a]pyrene Versus Fluoranthene (Both Compounds in ng/m^3)

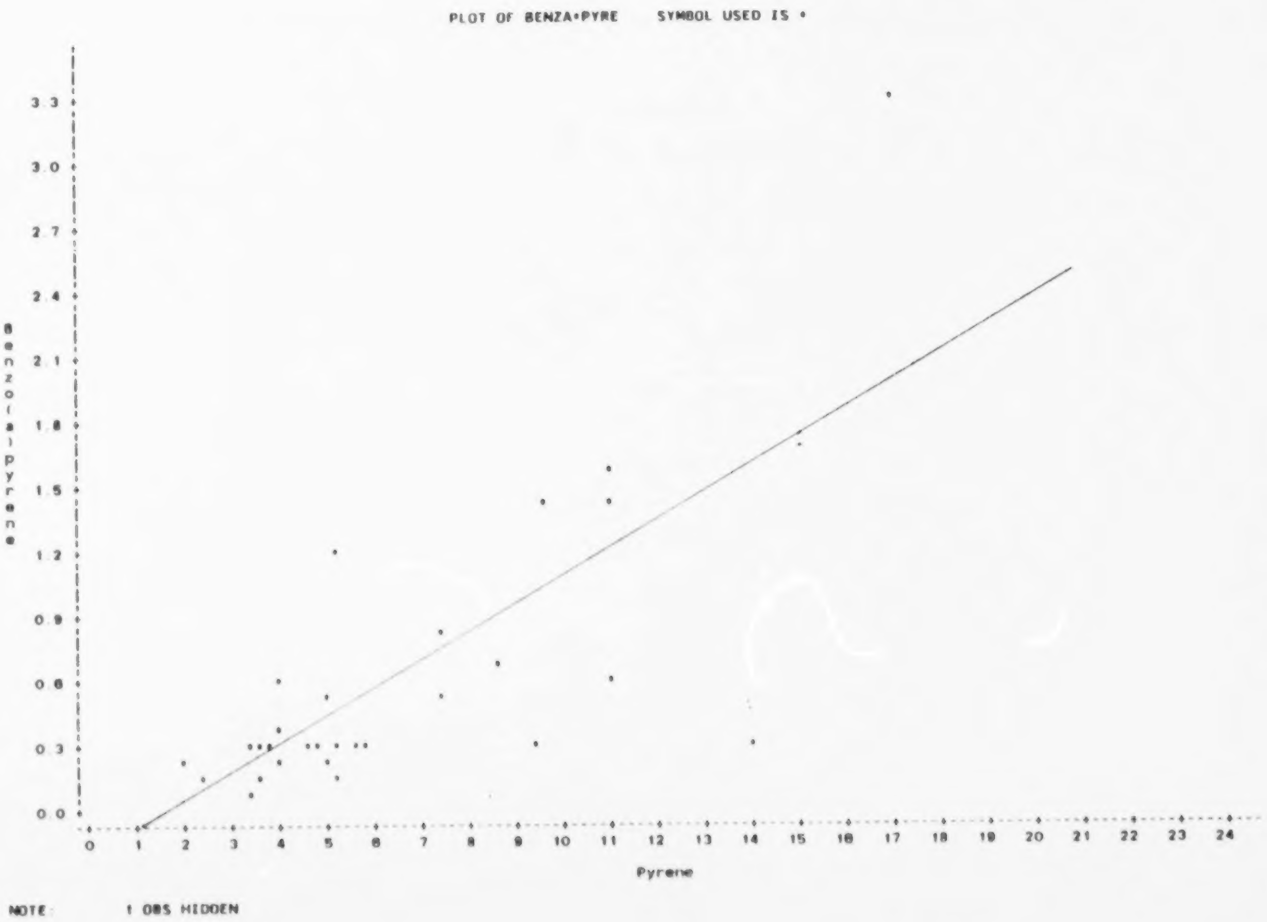

Figure 5.7 Plot of Concentration of Benzo[a]pyrene Versus Pyrene (Both Compounds in ng/m^3)

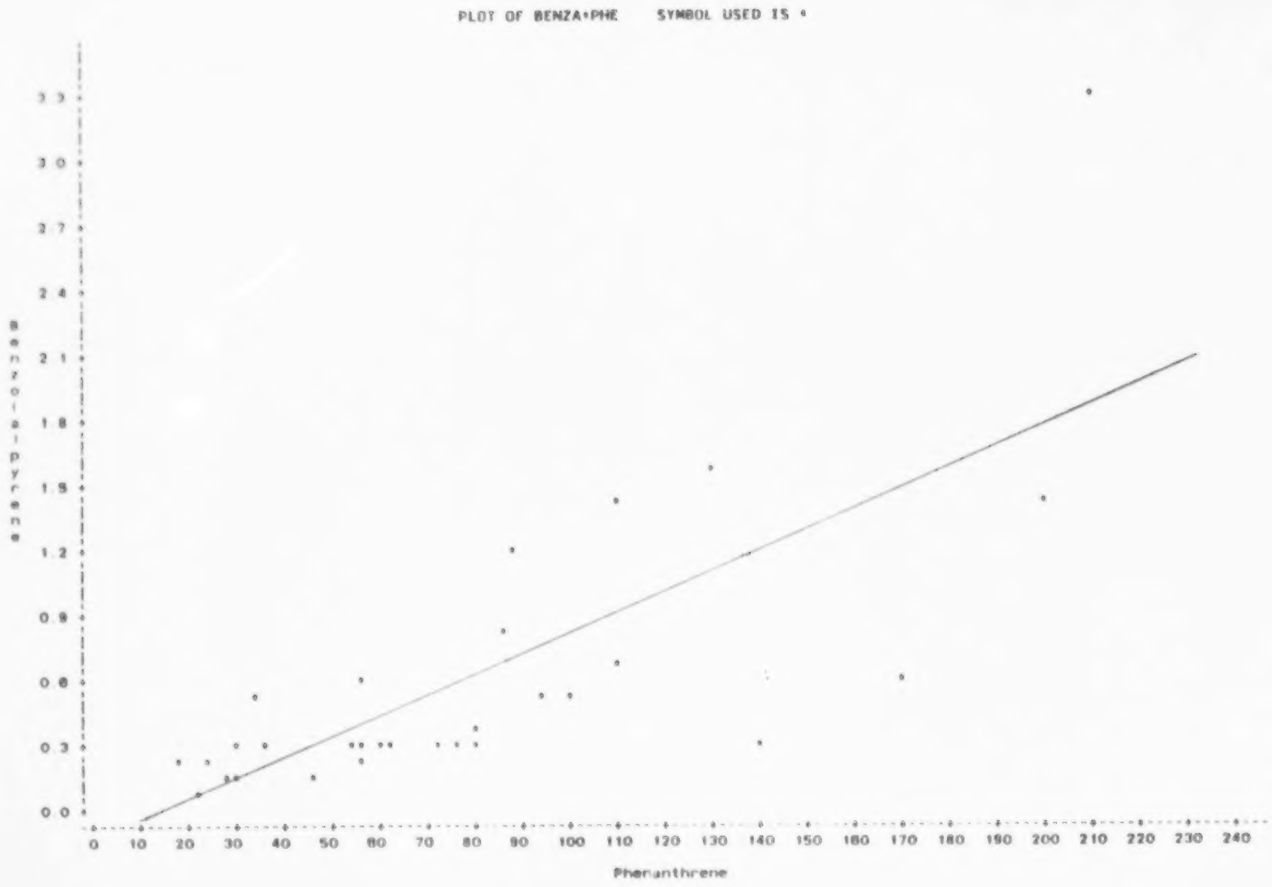

Figure 5.8 Plot of Concentration of Benzo[a]pyrene Versus Phenanthrene (Both Compounds in ng/m^3)

case there is a fair amount of variability in the level of the marker compound for any given level of BaP, but that there is definitely a positive relationship.

In order to use one compound as a marker for another, a predictive equation is needed to transform each measured level of the marker compound into an estimated level for the target compound. This equation is empirically generated by fitting a least-squares regression line through plotted pairs of measured levels of the marker and target compounds. We used the data from this range-finding study to fit simple linear regression lines for each target pollutant versus each of the three potential marker compounds fluoranthene, pyrene, and phenanthrene. Each regression equation uses the target compound level as the dependent (y) variable and the marker compound level as the independent (x) variable. An example is the regression equation we obtained for the target compound BaP versus the marker compound pyrene:

$$B\hat{a}P = -0.253 + 0.133^{*} \times \text{PYRENE } (\text{ng/m}^3) \ ,$$

where $B\hat{a}P$ denotes the predicted level of BaP, and PYRENE is the measured level of pyrene from which the BaP level is estimated. The R-SQUARE value for this predictive equation is 54 percent, which is a measure of the percent of total variability in the observed levels of BaP (from the range-finding study) that are estimated to be associated with variation in the levels of pyrene. A value of R-SQUARE near 100 percent indicates that the equation has very good predictive ability. A value of R-SQUARE near zero indicates the equation has very little predictive ability.

Prediction equations and R-SQUARE values for all combinations of each target compound with each of the three potential marker compounds are given in Appendix E.

The second part of our investigation of correlations between compounds addresses the relationship between PAH parent compounds and their nitro derivatives. In particular, we investigated the relationship between pyrene and its derivative 1-nitropyrene, and the compound fluoranthene and its derivative 2-nitrofluoranthene. The estimated correlation coefficients and significance levels for these two pairs of compounds are given in Table 5.23.

TABLE 5.23 CORRELATIONS AND SIGNIFICANCE LEVELS BETWEEN PAH PARENT COMPOUNDS AND THEIR DERIVATIVE COMPOUNDS

	Pyrene[a] 1-nitropyrene	Fluoranthene 2-nitrofluoranthene
Estimated Correlation	0.64	0.30
Significance Level	<0.01	0.11

[a] The outlier value of 0.83 ng/m^3 for 1-nitropyrene was omitted from this analysis.

In both cases the correlations are close to being statistically significant though the relationship for fluoranthene and 2-nitrofluoranthene is not as strong as we previously found between the potential PAH marker compounds and other PAH compounds. The correlations are positive, indicating that higher levels of the derivative compounds tend to be associated with higher levels of the parent compounds. Figures 5.9 and 5.10 present plots of measured levels of 1-nitropyrene and 2-nitrofluoranthene, respectively, against the levels of each respective parent compound. The plot for fluoranthene does not show as strong a relationship with its derivative as does the plot for pyrene.

The third part of our investigation of correlations between compounds addresses the correlation of nicotine with other pollutant compounds. Table 5.24 presents the estimated correlation coefficients and significance levels between nicotine and other pollutant compounds. Note from Table 5.24 that all correlations except one (naphthalene dicarboxylic acid anhydride) are positive and statistically significant. As an illustration of the relationship between nicotine and other compounds, Figure 5.11 presents a plot of the measured levels of nicotine versus BaP. Higher levels of nicotine clearly tend to be associated with higher levels of BaP.

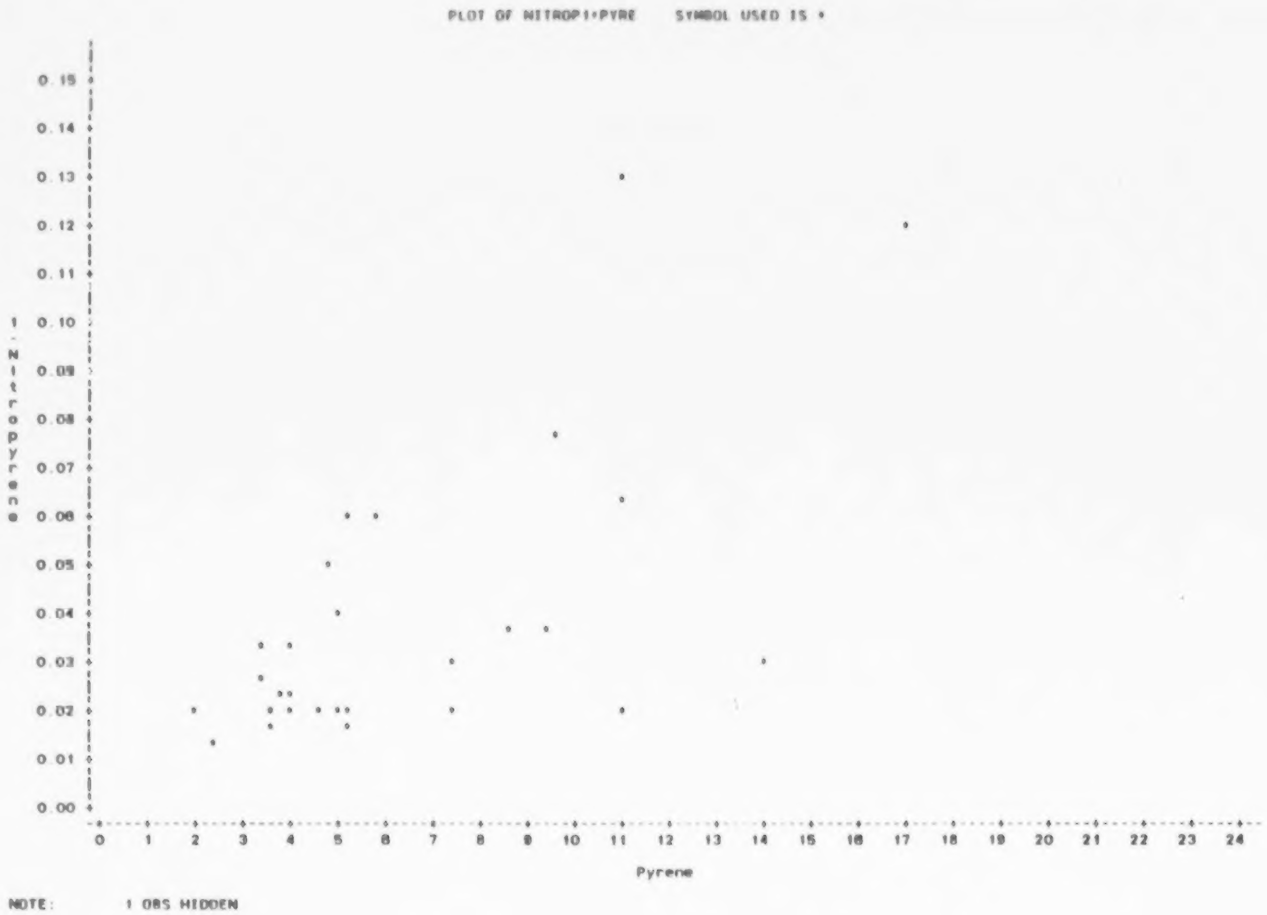

Figure 5.9 Plot of Concentration of 1-Nitropyrene Versus Pyrene (Both Compounds in ng/m^3)

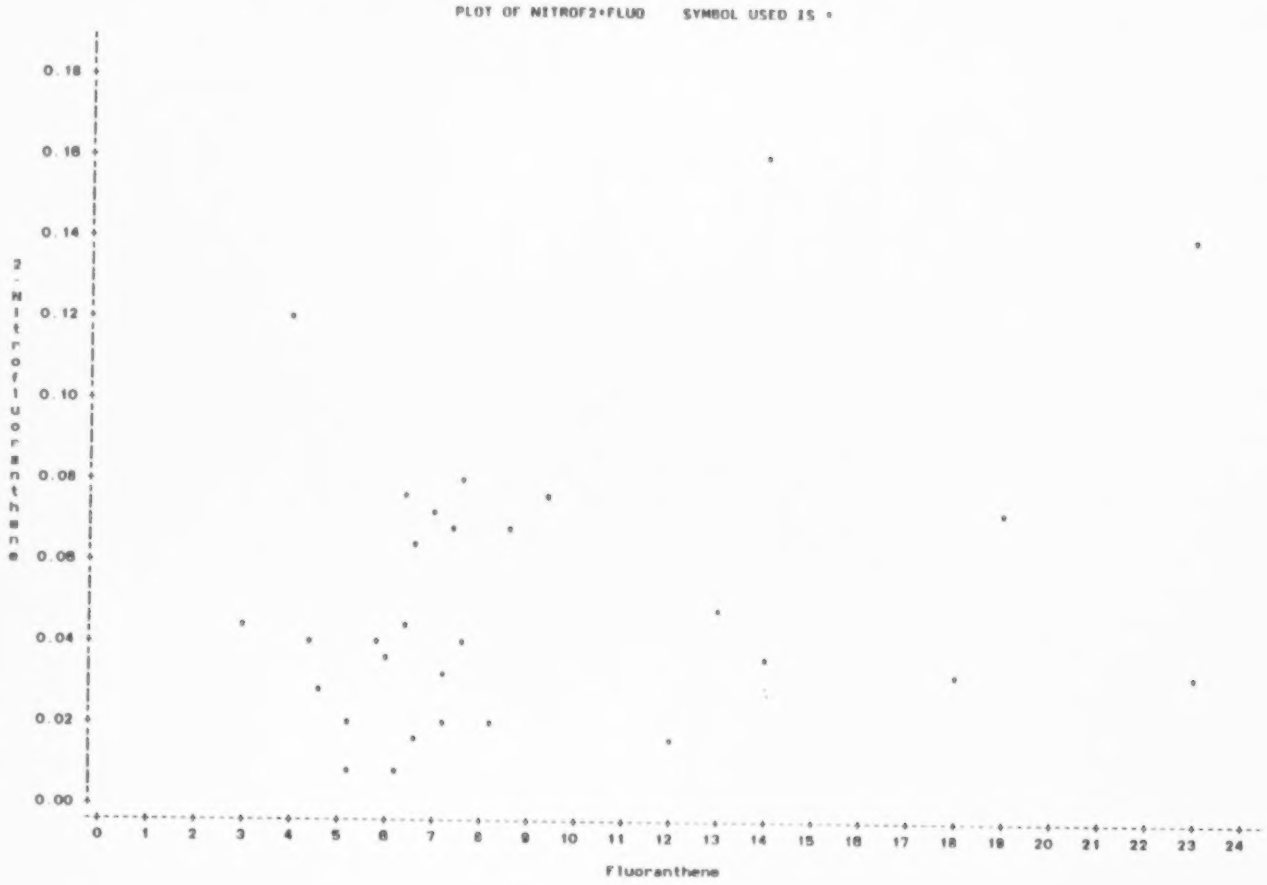

Figure 5.10 Plot of Concentration of 2-Nitrofluoranthene Versus Fluoranthene (Both Compounds in ng/m3)

TABLE 5-24. ESTIMATED CORRELATION COEFFICIENTS AND STATISTICAL SIGNIFICANCE LEVELS FOR RELATIONSHIPS BETWEEN NICOTINE AND OTHER POLLUTANT COMPOUNDS

	Nicotine
Naphthalene	0.36693 0.0461
Acenaphthylene	0.89611 0.0001
Anthracene	0.88959 0.0001
Cyclopenta[c,d]pyrene	0.92799 0.0001
Benz[a]anthracene	0.90513 0.0001
Chrysene	0.91897 0.0001
Benzofluoranthenes	0.79756 0.0001
Benzo[e]pyrene	0.84780 0.0001
Benzo[a]pyrene	0.91575 0.0001
Ideno[1,2,3-c,d]pyrene	0.76572 0.0001
Benzo[g,h,i]perylene	0.84585 0.0001
Coronene	0.39734 0.0297
Quinoline	0.96389 0.0001
Isoquinoline	0.96987 0.0001
Total PAH	0.39338 0.0315

TABLE 5-24. ESTIMATED CORRELATION COEFFICIENTS AND STATISTICAL SIGNIFICANCE LEVELS FOR RELATIONSHIPS BETWEEN NICOTINE AND OTHER POLLUTANT COMPOUNDS (Continued)

	Nicotine
Fluorenone	0.88245 0.0001
Naphthalene dicarboxylic acid anhydride	-0.03254 0.8644
9-Nitroanthracene isomer	0.68127 0.0001
9-Nitroanthracene	0.25897 0.1670
9-Nitrophenanthrene	0.85398 0.0001
Pyrene carboxaldehyde	0.81317 0.0001
2-Nitrofluoranthene	0.64059 0.0001
1-Nitropyrene	0.83126 0.0001
Benz[a]anthracene-7, 12-dione	0.72869 0.0001
Pyrene-3,4-dicarboxylic acid anhydride	0.01860 0.9223
Total Extractable Organic Mass	0.82997 0.0001
Fluoranthene	0.60974 0.0003
Pyrene	0.65588 0.0001
Phenanthrene	0.73203 0.0001

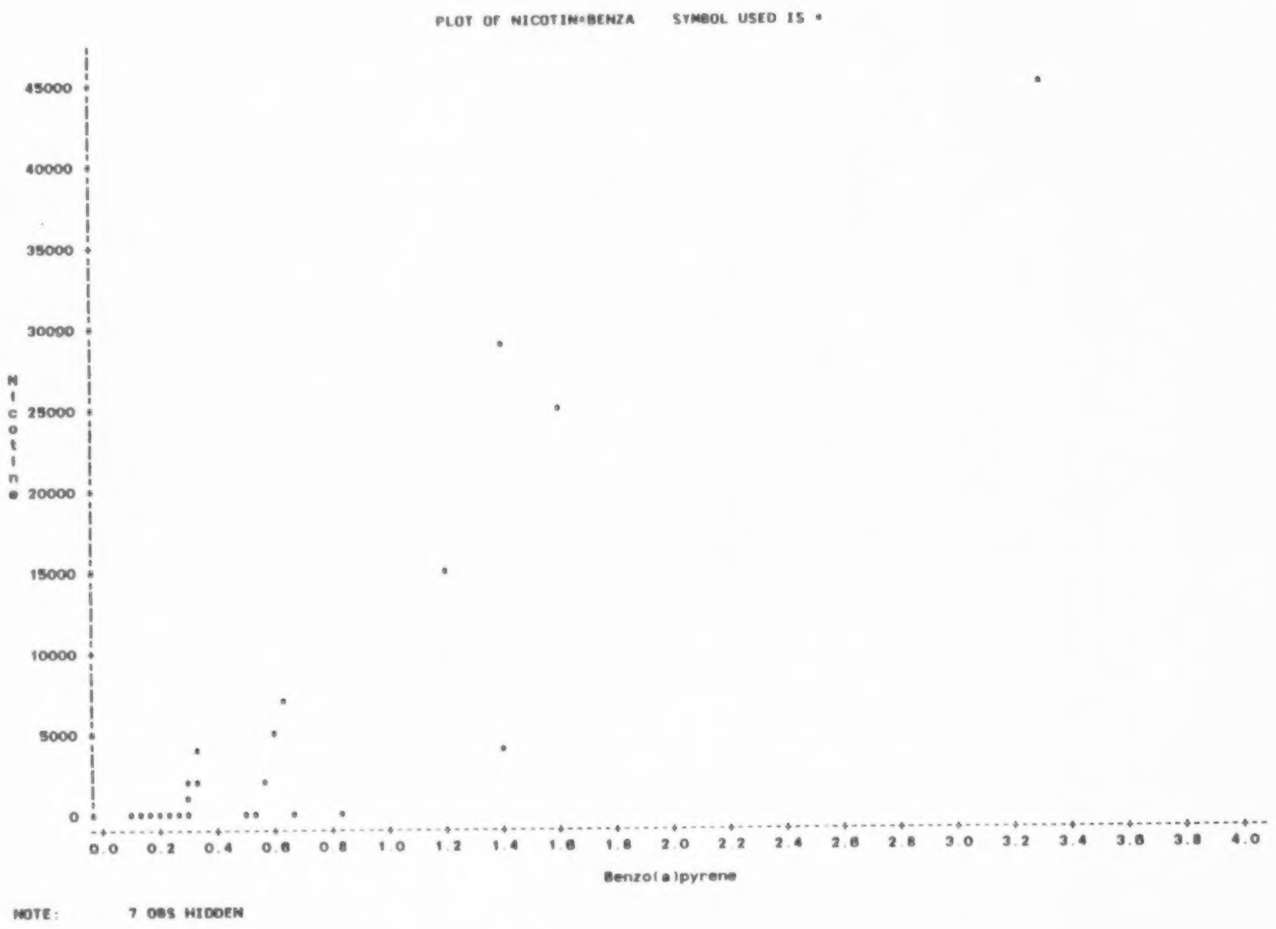

Figure 5.11 Plot of Concentration of Nicotine Against Benzo[a]pyrene (ng/m^3)

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APPENDIX A

Activity Logs for the Sampled Homes

INDOOR AIR SAMPLING FORM

House ID 1 Date 3/14/87 Operators: CB

House Style: 2 story Y Ranch ___ Split ___

Heating: Gas Y Electric ___ House sq ft 1400 (approx)

Cooking: Gas ___ Electric Y Ceiling Height 8' 6" (ft)

Pilot Lights?: N Attached Garage?: N

Fireplace or Aux Heaters?: N House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 1 Sampler ID B

Filter 1

Start Time: 0700 End Time: 1500

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
0700	68	20

3-11 (Living Room)

Sample: XAD 3

Filter 3

Start Time: 1520 End Time: 2300

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
2005	70	24

OUTDOOR SAMPLE

Sampler ID 94 Sample XAD 2 Filter 2

Start Time: 0701 End Time: 2301

Time	Flow ("H20)	Temp (F)	RH (%)
0715	40	39	31
2015	41.5	50	56

Weather?: None

SF_6 Injection: 10 cc at time 1730

SF_6 Sample 1 Time: 1835

SF_6 Sample 2 Time: 2145

RESIDENT ACTIVITY FORM

House ID 1

Sampling Date 3/14/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

Stove on at 0820 -- frying eggs and bacon

0820-1500 -- simmering coffee

Oven on 1345-1430 -- buns and chicken

Stove on 1700-1705 -- heating milk

Stove on 1730-1735 -- noodles

Stove on 1950-2050 -- spaghetti/sauce/tea

Stove on 2120-2130 -- hot chocolate

Number of house entries plus exits: 7:00 a.m.-3:00 p.m. 2
3:00 p.m.-11:00 p.m. 8

Number of cigarettes smoked: 7:00 a.m.-3:00 p.m. None
3:00 p.m.-11:00 p.m. None
Brand N/A

INDOOR AIR SAMPLING FORM

House ID 2 Date 3/15/87 Operators: CB

House Style: 2 story Y Ranch ____ Split ____

Heating: Gas Y Electric ____ House sq ft 1250 (approx)

Cooking: Gas Y Electric ____ Ceiling Height 8' (ft)

Pilot Lights?: N Attached Garage?: N

Fireplace or Aux Heaters?: N House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 5 Sampler ID C

Filter 5

Start Time: 0710 End Time: 1500

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
0940	72	20

3-11 (Living Room)

Sample: XAD 6

Filter 6

Start Time: 1530 End Time: 2300

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1530	73	22

OUTDOOR SAMPLE

Sampler ID 90 Sample XAD 4 Filter 4

Start Time: 0700 End Time: 2300

Time	Flow ("H20)	Temp (F)	RH (%)
0700	40	37	68
1600	39.5	42	71
2300	39.5	38	81

Weather?: Overcast

SF_6 Injection: 10 cc at time 0945

SF_6 Sample 1 Time: 1300

SF_6 Sample 2 Time: 1945

RESIDENT ACTIVITY FORM

House ID 2 Sampling Date 3/15/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

1000-1100 -- fry bacon and french toast

1730-1840 -- fry

1730-1800 -- oven

Number of house entries plus exits: 7:00 a.m.-3:00 p.m. 8
3:00 p.m.-11:00 p.m. 14

Number of cigarettes smoked: 7:00 a.m.-3:00 p.m. 10
3:00 p.m.-11:00 p.m. 16
Brand Merits/Camels

INDOOR AIR SAMPLING FORM

House ID 3 Date 3/17/87 Operators: CB/MRK

House Style: 2 story ____ Ranch ____ Split Y

Heating: Gas ____ Electric Y House sq ft 800 (approx)

Cooking: Gas ____ Electric Y Ceiling Height 8 (ft)

Pilot Lights?: N Attached Garage?: Y

Fireplace or Aux Heaters?: N House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 7 Sampler ID C

Filter 7

Start Time: 0706 End Time: 1550

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
0700	71	33

3-11 (Living Room)

Sample: XAD 9

Filter 9

Start Time: 1615 End Time: 2255

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1615	75	28

OUTDOOR SAMPLE

Sampler ID 90 Sample XAD 8 Filter 8

Start Time: 0700 End Time: 2255

Time	Flow ("H20)	Temp (F)	RH (%)
0700	40	37	35
1620	42	58	19

Weather?: None

SF_6 Injection: 10 cc at time 0700

SF_6 Sample 1 Time: 1110

SF_6 Sample 2 Time: 1550

RESIDENT ACTIVITY FORM

House ID 3

Sampling Date 3/17/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

0715 -- cooked four eggs (scrambled) in open frying pan; also made four pieces of toast in toaster

1815 -- heated (boiled) water for spaghetti; warmed spaghetti sauce in small pan

Number of house entries plus exits: 7:00 a.m.-4:15 p.m. 31
4:15 p.m.-11:00 p.m. 25

Number of cigarettes smoked: 7:00 a.m.-4:15 p.m. 6
4:15 p.m.-11:00 p.m. 9
Brand Marlboro Reg

INDOOR AIR SAMPLING FORM

House ID 3-3 Date 4/4/87 Operators: CB/RNS
House Style: 2 story ____ Ranch ____ Split Y
Heating: Gas ____ Electric Y House sq ft 800 (approx)
Cooking: Gas ____ Electric Y Ceiling Height 8 (ft)
Pilot Lights?: N/A Attached Garage?: Y
Fireplace or Aux Heaters?: N House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 35 Sampler ID C
Filter 35
Start Time: 0700 End Time: 1515
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
0710	71	36
1520	72	38

3-11 (Living Room)

Sample: XAD 37
Filter 37
Start Time: 1525 End Time: 2300
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1525	72	38

OUTDOOR SAMPLE

Sampler ID 90 Sample XAD 36 Filter 36
Start Time: 0700 End Time: 2300

Time	Flow ("H20)	Temp (F)	RH (%)
0700	40	28	65
1525	40	35	80

Weather?: Snow
SF_6 Injection: 10 cc at time 1400
SF_6 Sample 1 Time: 1520
SF_6 Sample 2 Time: 1620
SF_6 Sample 3 Time: 1920

RESIDENT ACTIVITY FORM

House ID 3-3 Sampling Date 4/4/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

1230-1310 -- boil water w/eggs (hard boiled eggs)

1255-1305 -- scramble eggs in open frying pan

Number of house entries plus exits: 7:00 a.m.-3:00 p.m. 36
3:00 p.m.-11:00 p.m. 17

Number of cigarettes smoked: 7:00 a.m.-3:00 p.m. 4
3:00 p.m.-11:00 p.m. 0
Brand Marlboro

INDOOR AIR SAMPLING FORM

House ID 4 Date 3/18/87 Operators: CB/SH

House Style: 2 story Y Ranch ____ Split ____

Heating: Gas Y Electric ____

House sq ft 900 (approx)

Cooking: Gas Y Electric ____

Ceiling Height 8 (ft)

Pilot Lights?: Y

Attached Garage?: N

Fireplace or Aux Heaters?: N

House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 11 Sampler ID B

Filter 11

Start Time: 0700 End Time: 1500

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)

3-11 (Living Room)

Sample: XAD 13

Filter 13

Start Time: 1530 End Time: 2200

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)

OUTDOOR SAMPLE

Sampler ID 94 Sample XAD 12 Filter 12

Start Time: 0700 End Time: 2200

Time	Flow ("H20)	Temp (F)	RH (%)
0700	40	33	
1500	34	61	10
1500	Set back to 40" H20		
2200	40	45	

Weather?: Cloudy (overcast)

SF_6 Injection: 10 cc at time 1430

SF_6 Sample 1 Time: 1530

SF_6 Sample 2 Time: 1630

SF_6 Sample 3 Time: 1730

RESIDENT ACTIVITY FORM

House ID 4 Sampling Date 3/18/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

0830-0840 -- coffee

1000-1010 -- coffee

Number of house entries plus exits:	7:00 a.m.-3:00 p.m.	7
	3:00 p.m.-11:00 p.m.	9

Number of cigarettes smoked:	7:00 a.m.-3:00 p.m.	7
	3:00 p.m.-11:00 p.m.	15
	Brand	Kools Ultra

INDOOR AIR SAMPLING FORM

House ID 5 Date 3/19/87 Operators: RNS/CB
House Style: 2 story Y Ranch ____ Split ____ **(Apartment)**
Heating: Gas Y Electric ____ House sq ft 800 (approx)
Cooking: Gas ____ Electric Y Ceiling Height 8 (ft)
Pilot Lights?: N Attached Garage?: N
Fireplace or Aux Heaters?: N House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 15 Sampler ID C
Filter 15
Start Time: 0700 End Time: 1500
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
0700	68	
1440	77	19

3-11 (Living Room)

Sample: XAD 14
Filter 14
Start Time: 1515 End Time: 2300
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1515	80	17
1445	8	20

OUTDOOR SAMPLE

Sampler ID 90 Sample XAD 16 Filter 16
Start Time: 0700 End Time: 2300

Time	Flow ("H20)	Temp (F)	RH (%)
0700	40	39	
1450	36	67	10
2200	36	49	13

Weather?: Clear
SF_6 Injection: 10 cc at time 2000
SF_6 Sample 1 Time: 2145
SF_6 Sample 2 Time: 2250

RESIDENT ACTIVITY FORM

House ID 5 Sampling Date 3/20/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

1200-1210 -- grilled cheese
0700-0730 -- boiled water
2000-2130 -- chicken and noodles

Number of house entries plus exits: 7:00 a.m.-3:00 p.m. 6
3:00 p.m.-11:00 p.m. 10

Number of cigarettes smoked: 7:00 a.m.-3:00 p.m. 11
3:00 p.m.-11:00 p.m. 20
Brand Kools/Winston

INDOOR AIR SAMPLING FORM

House ID 6 Date 3/23/87 Operators: MRK/CB

House Style: 2 story ____ Ranch Y Split ____

Heating: Gas Y Electric ____ House sq ft 1750 (approx)

Cooking: Gas ____ Electric Y Ceiling Height 8 (ft)

Pilot Lights?: N Attached Garage?: In basement

Fireplace or Aux Heaters?: Y, but unused House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 20 Sampler ID C

Filter 20

Start Time: 0500 End Time: 1600

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1600	80	40

3-11 (Living Room)

Sample: XAD 21

Filter 21

Start Time: 1620 End Time: 2300

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1625	80	40
2259	76	27

OUTDOOR SAMPLE

Sampler ID 90 Sample XAD 19 Filter 19

Start Time: 0500 End Time: 2300

Time	Flow ("H20)	Temp (F)	RH (%)
0500	40	44	
1625	40	71	
2300	40	58	28

Weather?: Clear

SF_6 Injection: 10 cc at time 1615

SF_6 Sample 1 Time: 1700

SF_6 Sample 2 Time: 1800

RESIDENT ACTIVITY FORM

House ID 6 Sampling Date 3/23/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

0502-0515 -- fried ham and eggs on electric range

0515-0540 -- boiled water

0545-0600 -- simmered coffee

1700-1730 -- fried hamburger and simmered stew on conventional range

1745-1800 -- baked bran muffins in conventional oven

Number of house entries plus exits: 7:00 a.m.-3:00 p.m. 6
3:00 p.m.-11:00 p.m. 4

Number of cigarettes smoked: 5:00 a.m.-6:04 a.m. 9
3:00 p.m.-11:00 p.m. 12
Brand Winston Filters

INDOOR AIR SAMPLING FORM

House ID 7 Date 3/25/87 Operators: CB
House Style: 2 story Y Ranch ____ Split ____
Heating: Gas ____ Electric Y
House sq ft 1800 (approx)
Cooking: Gas ____ Electric Y
Ceiling Height 8 (ft)
Pilot Lights?: N/A
Attached Garage?: Y
Fireplace or Aux Heaters?: ______
House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 22 Sampler ID C
Filter 22
Start Time: 0700 End Time: 1605
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)

3-11 (Living Room)

Sample: XAD 24
Filter 24
Start Time: 1625 End Time: 2300
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1625	70	63
2300	71	65

OUTDOOR SAMPLE

Sampler ID 90 Sample XAD 23 Filter 23
Start Time: 0700 End Time: 2300

Time	Flow ("H20)	Temp (F)	RH (%)
0700	40		62
1620	39	57	62
2300	40	52	65

Weather?: Cloudy
SF_6 Injection: 10 cc at time 1630
SF_6 Sample 1 Time: 1800
SF_6 Sample 2 Time: 1910

RESIDENT ACTIVITY FORM

House ID 7

Sampling Date 3/25/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

0930-0945 -- eggs
0945-1000 -- water
1610-1620 -- water
1900-1930 -- frying meat; boiling water

Number of house entries plus exits: 7:00 a.m.-3:00 p.m. 7
3:00 p.m.-11:00 p.m. 9

Number of cigarettes smoked: 7:00 a.m.-3:00 p.m. None
3:00 p.m.-11:00 p.m. None
Brand N/A

INDOOR AIR SAMPLING FORM

House ID 8 Date 3/26/87 Operators: RNS/CB

House Style: 2 story ____ Ranch ____ Split Y

Heating: Gas Y Electric ____ House sq ft 1800 (approx)

Cooking: Gas Y Electric ____ Ceiling Height 8½ (ft)

Pilot Lights?: Y Attached Garage?: N

Fireplace or Aux Heaters?: N House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 25 Sampler ID B

Filter 25

Start Time: 0700 End Time: 1500

Start Flow: 8 (cfm)

End Flow: 7.9 (cfm)

Time	Temp (F)	RH (%)
1450	69	35

3-11 (Living Room)

Sample: XAD 27

Filter 27

Start Time: 1520 End Time: 2221

Start Flow: 8 (cfm)

End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1525	69	35

OUTDOOR SAMPLE

Sampler ID 94 Sample XAD 26 Filter 26

Start Time: 0700 End Time: 2221

Time	Flow ("H20)	Temp (F)	RH (%)
0700	40		
1450	40	58	60
2221	40	51	99

Weather?: Cloudy

SF_6 Injection: ____ cc at time ____

SF_6 Sample 1 Time: ____

SF_6 Sample 2 Time: ____

RESIDENT ACTIVITY FORM

House ID 8 Sampling Date 3/26/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

0735-0755 -- bacon and pancakes
1020-1028 -- water boiled
1155-1214 -- grilled cheese sandwiches
1200-1204 -- chicken soup
1700-1735 -- sauce and spaghetti
1800-1805
1830-1834 -- tea reheat

Number of house entries plus exits:	7:00 a.m.-3:00 p.m.	20
	3:00 p.m.-11:00 p.m.	20

Number of cigarettes smoked:	7:00 a.m.-3:00 p.m.	None
	3:00 p.m.-11:00 p.m.	None
	Brand	N/A

INDOOR AIR SAMPLING FORM

House ID 8-2 Date 3/27/87 Operators: MRK/CB
House Style: 2 story ____ Ranch ____ Split Y
Heating: Gas Y Electric ____ House sq ft 1800 (approx)
Cooking: Gas Y Electric ____ Ceiling Height 8½ (ft)
Pilot Lights?: N Attached Garage?: N
Fireplace or Aux Heaters?: N House Sketches?: Y

INDOOR SAMPLES

7-3 (Kitchen)

Sample: XAD 29 Sampler ID B
Filter 29
Start Time: 0700 End Time: 1500
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1435	71	Inst down

3-11 (Living Room)

Sample: XAD 30
Filter 30
Start Time: 1515 End Time: 2249
Start Flow: 8 (cfm)
End Flow: 8 (cfm)

Time	Temp (F)	RH (%)
1515	71	Inst down

OUTDOOR SAMPLE

Sampler ID 94 Sample XAD 28 Filter 28
Start Time: 0700 End Time: 2250

Time	Flow ("H20)	Temp (F)	RH (%)
2300	40		
1520	40	65	
2250	43		

Weather?: None
SF$_6$ Injection: ____ cc at time ____
SF$_6$ Sample 1 Time: ____
SF$_6$ Sample 2 Time: ____

RESIDENT ACTIVITY FORM

House ID 8-2 Sampling Date 3/27/87

Cooking times (beginning and end) and type:
e.g., frying bacon and eggs 0700-0715; simmering coffee 0700-0800; boiling water 0730-0740.

Please include all cooking performed on range or in oven:

0728-0739 -- boil water
0730-0735 -- boil cream of wheat
1745-1800 -- brown meat; cook chili
1752-1757 -- boil water

Number of house entries plus exits: 7:00 a.m.-3:00 p.m. 34
3:00 p.m.-11:00 p.m. 22

Number of cigarettes smoked: 7:00 a.m.-3:00 p.m. None
3:00 p.m.-11:00 p.m. None
Brand N/A

APPENDIX B

Observed Target Compound Levels for All Homes and Sampling Locations

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Naphthalene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	550.000	800.000	170.000
2	860.000	1100.000	200.000
3 DAY 1	1200.000	1100.000	110.000
3 DAY 2	1700.000	1300.000	130.000
4	810.000	1100.000	210.000
5	1700.000	2200.000	330.000
6	1800.000	4200.000	120.000
7	750.000	1800.000	110.000
8 DAY 1	1400.000	880.000	150.000
8 DAY 2	1000.000	1300.000	180.000

Concentrations - nanograms/cubic meter

COMPOUND =Acenaphthylene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	12.000	18.000	3.100
2	23.000	37.000	10.000
3 DAY 1	18.000	17.000	0.590
3 DAY 2	18.000	17.000	4.900
4	25.000	48.000	4.600
5	63.000	120.000	8.900
6	41.000	59.000	1.100
7	11.000	10.000	4.600
8 DAY 1	19.000	8.900	1.700
8 DAY 2	13.000	14.000	3.800

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Phenanthrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	55.000	71.000	35.000
2	56.000	87.000	29.000
3 DAY 1	94.000	80.000	17.000
3 DAY 2	80.000	61.000	23.000
4	170.000	200.000	34.000
5	130.000	210.000	54.000
6	76.000	110.000	22.000
7	55.000	59.000	29.000
8 DAY 1	140.000	86.000	28.000
8 DAY 2	100.000	110.000	46.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Anthracene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	1.800	5.000	0.920
2	5.300	11.000	1.500
3 DAY 1	5.000	4.600	0.550
3 DAY 2	2.800	1.700	2.000
4	7.200	12.000	0.830
5	8.000	15.000	1.600
6	4.000	6.000	0.280
7	1.500	2.000	0.640
8 DAY 1	3.500	0.760	0.460
8 DAY 2	3.000	1.700	0.790

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Fluoranthene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	7.400	7.600	6.500
2	5.800	8.600	6.000
3 DAY 1	8.100	6.500	3.000
3 DAY 2	7.200	5.100	5.100
4	18.000	19.000	6.400
5	14.000	23.000	9.400
6	7.600	6.400	3.900
7	6.200	7.200	4.300
8 DAY 1	23.000	12.000	4.600
8 DAY 2	13.000	14.000	7.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Pyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	4.900	4.600	3.800
2	3.900	5.200	5.100
3 DAY 1	5.000	4.000	1.900
3 DAY 2	4.700	3.300	3.900
4	11.000	11.000	4.900
5	11.000	17.000	9.400
6	5.700	9.500	3.400
7	3.600	5.600	5.100
8 DAY 1	14.000	7.400	2.300
8 DAY 2	7.400	8.600	3.500

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Cyclopenta(c,d)pyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.140	0.120	0.090
2	0.340	1.100	0.170
3 DAY 1	0.200	0.200	0.090
3 DAY 2	0.230	0.170	0.080
4	0.350	0.870	0.180
5	1.300	2.000	0.340
6	0.240	0.850	0.120
7	0.180	0.190	0.190
8 DAY 1	0.400	0.290	0.050
8 DAY 2	0.140	0.130	0.090

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Benz(a)anthracene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.390	0.290	0.420
2	0.700	1.400	0.600
3 DAY 1	0.450	0.330	0.220
3 DAY 2	0.340	0.170	0.830
4	0.660	1.600	0.830
5	1.600	3.400	0.580
6	0.350	1.400	0.180
7	0.250	0.240	0.230
8 DAY 1	0.430	1.000	0.140
8 DAY 2	0.340	0.410	0.200

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Chrysene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.860	0.750	1.000
2	1.600	2.600	1.400
3 DAY 1	1.300	0.940	0.590
3 DAY 2	0.910	0.480	1.400
4	1.400	3.500	1.600
5	3.700	7.200	2.200
6	1.100	2.400	0.820
7	0.580	0.930	1.100
8 DAY 1	1.600	1.200	0.360
8 DAY 2	1.400	2.000	0.510

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Benzofluoranthenes

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	1.200	0.740	1.400
2	1.700	2.500	1.700
3 DAY 1	1.000	0.920	0.640
3 DAY 2	0.710	0.510	1.500
4	1.200	2.700	2.300
5	2.900	5.100	1.400
6	0.830	2.000	0.610
7	0.580	0.780	0.510
8 DAY 1	1.500	2.500	0.480
8 DAY 2	1.600	2.500	0.740

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Benzo(e)pyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.550	0.490	0.560
2	1.500	3.200	0.690
3 DAY 1	2.500	1.300	0.260
3 DAY 2	1.100	0.570	0.640
4	1.100	3.700	0.880
5	4.500	10.000	0.630
6	0.890	6.500	0.240
7	0.330	0.680	0.280
8 DAY 1	0.880	1.400	0.210
8 DAY 2	0.710	1.200	0.290

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Benzo(a)pyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.250	0.280	0.290
2	0.620	1.200	0.310
3 DAY 1	0.560	0.340	0.200
3 DAY 2	0.300	0.290	0.220
4	0.600	1.400	0.540
5	1.600	3.300	0.300
6	0.320	1.400	0.100
7	0.280	0.310	0.150
8 DAY 1	0.310	0.830	0.140
8 DAY 2	0.490	0.670	0.130

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Indeno(1,2,3-c,d)pyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.440	0.350	0.460
2	0.830	0.970	0.510
3 DAY 1	0.350	0.400	0.170
3 DAY 2	0.340	0.300	0.440
4	0.740	1.000	0.740
5	1.000	1.800	0.430
6	0.180	1.300	0.160
7	0.310	0.240	0.180
8 DAY 1	0.400	1.000	0.230
8 DAY 2	0.480	0.700	0.260

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Benzo(g,h,i)perylene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.660	0.510	0.600
2	0.640	1.400	0.740
3 DAY 1	0.500	0.510	0.230
3 DAY 2	0.710	0.410	0.460
4	1.100	1.600	1.100
5	1.400	2.500	0.810
6	0.390	1.400	0.200
7	0.550	0.320	0.270
8 DAY 1	0.480	1.100	0.280
8 DAY 2	0.660	0.740	0.440

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Coronene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.440	0.370	0.390
2	0.550	0.600	0.460
3 DAY 1	0.170	0.330	0.100
3 DAY 2	0.500	0.250	0.170
4	1.100	0.640	0.590
5	1.400	0.640	0.680
6	0.190	1.400	0.090
7	0.660	0.310	0.180
8 DAY 1	0.230	0.810	0.260
8 DAY 2	0.260	0.460	0.320

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Nicotine

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	45.000	170.000	4.800
2	6800.000	15000.000	7.400
3 DAY 1	2000.000	1700.000	7.800
3 DAY 2	1800.000	700.000	4.900
4	4500.000	29000.000	12.000
5	25000.000	45000.000	29.000
6	4300.000	4100.000	1.900
7	200.000	24.000	5.100
8 DAY 1	63.000	60.000	14.000
8 DAY 2	48.000	69.000	9.900

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Quinoline

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	8.500	9.400	4.200
2	94.000	240.000	2.400
3 DAY 1	84.000	76.000	0.780
3 DAY 2	120.000	91.000	5.500
4	170.000	480.000	3.400
5	640.000	1100.000	4.000
6	180.000	300.000	2.500
7	28.000	23.000	2.500
8 DAY 1	11.000	9.100	3.000
8 DAY 2	9.000	13.000	4.800

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Isoquinoline

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	12.000	21.000	14.000
2	55.000	140.000	5.100
3 DAY 1	40.000	34.000	4.300
3 DAY 2	47.000	36.000	4.500
4	110.000	300.000	11.000
5	340.000	620.000	12.000
6	89.000	170.000	4.900
7	67.000	35.000	10.000
8 DAY 1	8.100	16.000	9.600
8 DAY 2	18.000	19.000	17.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Fluorenone

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	4.600	4.600	3.400
2	3.000	10.000	4.200
3 DAY 1	6.800	7.700	3.400
3 DAY 2	8.400	6.300	2.800
4	16.000	17.000	3.900
5	33.000	40.000	9.200
6	11.000	12.000	3.800
7	6.600	7.400	3.700
8 DAY 1	10.000	6.200	2.900
8 DAY 2	9.000	9.100	4.500

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Naphthaline dicarboxylic acid anhydride

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	5.000	4.200	8.300
2	5.000	3.400	11.000
3 DAY 1	2.000	1.700	7.800
3 DAY 2	1.700	1.300	14.000
4	4.400	6.800	9.900
5	6.000	6.200	9.400
6	4.600	3.600	10.000
7	1.900	7.200	9.700
8 DAY 1	4.300	2.400	4.800
8 DAY 2	3.600	3.000	10.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=9-Nitroanthracene isomer

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.150	0.200	0.200
2	0.380	0.360	0.290
3 DAY 1	0.410	0.530	0.180
3 DAY 2	0.310	0.250	0.240
4	0.380	0.710	0.150
5	1.100	0.950	0.510
6	0.750	0.910	0.500
7	0.220	0.450	0.570
8 DAY 1	0.440	0.290	0.260
8 DAY 2	0.320	0.310	0.420

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=9-Nitroanthracene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.120	0.170	0.084
2	0.400	0.360	0.057
3 DAY 1	0.110	0.150	0.012
3 DAY 2	0.043	0.039	0.032
4	0.120	0.480	0.086
5	0.250	0.320	0.100
6	0.180	0.085	0.029
7	0.049	0.130	0.036
8 DAY 1	1.300	0.290	0.051
8 DAY 2	0.250	0.160	0.060

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=9-Nitrophenanthrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.035	0.031	0.033
2	0.040	0.100	0.019
3 DAY 1	0.023	0.034	0.003
3 DAY 2	0.024	0.008	0.039
4	0.026	0.045	0.027
5	0.190	0.250	0.014
6	0.038	0.092	0.010
7	0.014	0.043	0.027
8 DAY 1	0.058	0.023	0.018
8 DAY 2	0.021	0.020	0.005

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Pyrene carboxaldehyde

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.049	0.035	0.051
2	0.140	0.300	0.100
3 DAY 1	0.062	0.100	0.035
3 DAY 2	0.110	0.039	0.130
4	0.060	0.210	0.080
5	0.340	0.330	0.120
6	0.260	0.090	0.035
7	0.021	0.023	0.035
8 DAY 1	0.028	0.023	0.019
8 DAY 2	0.057	0.051	0.035

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=2-Nitrofluoranthene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.066	0.041	0.064
2	0.038	0.067	0.037
3 DAY 1	0.021	0.017	0.042
3 DAY 2	0.030	0.009	0.021
4	0.031	0.071	0.077
5	0.160	0.140	0.075
6	0.079	0.042	0.120
7	0.009	0.020	0.041
8 DAY 1	0.031	0.017	0.027
8 DAY 2	0.049	0.036	0.072

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=1-Nitropyrene

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.039	0.021	0.022
2	0.034	0.059	0.020
3 DAY 1	0.019	0.021	0.020
3 DAY 2	0.050	0.026	0.023
4	0.020	0.063	0.021
5	0.130	0.120	0.036
6	0.059	0.076	0.033
7	0.019	0.830	0.017
8 DAY 1	0.030	0.021	0.012
8 DAY 2	0.029	0.036	0.018

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Benz(a)anthracene-7,12-dione

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.200	0.180	0.250
2	0.380	0.690	0.310
3 DAY 1	0.230	0.270	0.140
3 DAY 2	0.300	0.120	0.290
4	0.170	0.590	0.260
5	0.740	0.840	0.370
6	0.500	0.230	0.150
7	0.088	0.230	0.170
8 DAY 1	0.410	0.320	0.110
8 DAY 2	0.430	0.750	0.170

CONCENTRATIONS - nanograms/cubic meter

COMPOUND=Pyrene-3,4-dicarboxylic acid anhydride

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.330	0.210	0.250
2	0.440	0.270	0.540
3 DAY 1	0.077	0.081	0.190
3 DAY 2	0.051	0.036	0.510
4	0.300	0.240	0.560
5	0.250	0.170	0.230
6	0.079	0.085	0.110
7	0.095	0.059	0.190
8 DAY 1	0.130	0.110	0.100
8 DAY 2	0.210	0.100	0.320

Concentrations - milligrams/cubic meter

COMPOUND =Total Extractable Organic Mass

	LOCATION		
	Kitchen	Living Room	Outdoor
	RESPONSE	RESPONSE	RESPONSE
	CONCENTRATION	CONCENTRATION	CONCENTRATION
HOME			
1	0.066	0.064	0.016
2	0.170	0.160	0.018
3 DAY 1	0.120	0.110	0.011
3 DAY 2	0.130	0.077	0.013
4	0.120	0.280	0.012
5	0.400	0.570	0.047
6	0.170	0.280	0.019
7	0.079	0.150	0.024
8 DAY 1	0.290	0.130	0.009
8 DAY 2	0.130	0.170	0.012

APPENDIX C

Summary Statistics Comparing Pollutant Levels Across Homes Having Different Types of Heating Systems and Cooking Appliances

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Naphthalene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	1216.667	475.219	3	750.000	1700.000
	Gas	Electric	6.667	1350.000	694.622	3	550.000	1800.000
		Gas	4.250	1017.500	267.379	4	810.000	1400.000
Living Room	Electric	Electric	3.000	1400.000	360.555	3	1100.000	1800.000
	Gas	Electric	10.667	2400.000	1708.801	3	800.000	4200.000
		Gas	7.750	1095.000	171.561	4	880.000	1300.000
Outdoor	Electric	Electric	.	116.667	11.547	3	110.000	130.000
	Gas	Electric	.	206.667	109.697	3	120.000	330.000
		Gas	.	185.000	26.458	4	150.000	210.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Acenaphthylene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	15.667	4.041	3	11.000	18.000
	Gas	Electric	6.667	38.667	25.580	3	12.000	63.000
		Gas	4.250	20.000	5.292	4	13.000	25.000
Living Room	Electric	Electric	3.000	14.667	4.041	3	10.000	17.000
	Gas	Electric	10.667	65.667	51.326	3	18.000	120.000
		Gas	7.750	26.975	18.598	4	8.900	48.000
Outdoor	Electric	Electric	.	3.363	2.406	3	0.590	4.900
	Gas	Electric	.	4.367	4.051	3	1.100	8.900
		Gas	.	5.025	3.535	4	1.700	10.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Phenanthrene

			CIGARETTE	RESPONSE				
LOCATION	FURNACE	COOKING	Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	76.333	19.757	3	55.000	94.000
	Gas	Electric	6.667	87.000	38.891	3	55.000	130.000
		Gas	4.250	116.500	49.487	4	56.000	170.000
Living Room	Electric	Electric	3.000	66.667	11.590	3	59.000	80.000
	Gas	Electric	10.667	130.333	71.696	3	71.000	210.000
		Gas	7.750	120.750	53.984	4	86.000	200.000
Outdoor	Electric	Electric	.	23.000	6.000	3	17.000	29.000
	Gas	Electric	.	37.000	16.093	3	22.000	54.000
		Gas	.	34.250	8.261	4	28.000	46.000

COMPOUND Anthracene

			CIGARETTE	RESPONSE				
LOCATION	FURNACE	COOKING	Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	3.100	1.769	3	1.500	5.000
	Gas	Electric	6.667	4.600	3.143	3	1.800	8.000
		Gas	4.250	4.750	1.909	4	3.000	7.200
Living Room	Electric	Electric	3.000	2.767	1.595	3	1.700	4.600
	Gas	Electric	10.667	8.667	5.508	3	5.000	15.000
		Gas	7.750	6.365	5.956	4	0.760	12.000
Outdoor	Electric	Electric	.	1.063	0.812	3	0.550	2.000
	Gas	Electric	.	0.933	0.660	3	0.280	1.600
		Gas	.	0.895	0.436	4	0.460	1.500

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Fluoranthene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	7.167	0.950	3	6.200	8.100
	Gas	Electric	6.667	9.667	3.754	3	7.400	14.000
		Gas	4.250	14.950	7.340	4	5.800	23.000
Living Room	Electric	Electric	3.000	6.267	1.069	3	5.100	7.200
	Gas	Electric	10.667	12.333	9.257	3	6.400	23.000
		Gas	7.750	13.400	4.348	4	8.600	19.000
Outdoor	Electric	Electric	.	4.133	1.060	3	3.000	5.100
	Gas	Electric	.	6.600	2.751	3	3.900	9.400
		Gas	.	6.000	1.020	4	4.600	7.000

COMPOUND Pyrene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	4.433	0.737	3	3.600	5.000
	Gas	Electric	6.667	7.200	3.315	3	4.900	11.000
		Gas	4.250	9.075	4.380	4	3.900	14.000
Living Room	Electric	Electric	3.000	4.300	1.179	3	3.300	5.600
	Gas	Electric	10.667	10.367	6.245	3	4.600	17.000
		Gas	7.750	8.050	2.419	4	5.200	11.000
Outdoor	Electric	Electric	.	3.633	1.617	3	1.900	5.100
	Gas	Electric	.	5.533	3.355	3	3.400	9.400
		Gas	.	3.950	1.310	4	2.300	5.100

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Cyclopenta(c,d)pyrene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.203	0.025	3	0.180	0.230
	Gas	Electric	6.667	0.560	0.643	3	0.140	1.300
		Gas	4.250	0.307	0.115	4	0.140	0.400
Living Room	Electric	Electric	3.000	0.187	0.015	3	0.170	0.200
	Gas	Electric	10.667	0.990	0.948	3	0.120	2.000
		Gas	7.750	0.597	0.462	4	0.130	1.100
Outdoor	Electric	Electric	.	0.120	0.061	3	0.080	0.190
	Gas	Electric	.	0.183	0.137	3	0.090	0.340
		Gas	.	0.122	0.063	4	0.050	0.180

COMPOUND Benz(a)anthracene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.347	0.100	3	0.250	0.450
	Gas	Electric	6.667	0.780	0.710	3	0.350	1.600
		Gas	4.250	0.532	0.175	4	0.340	0.700
Living Room	Electric	Electric	3.000	0.247	0.080	3	0.170	0.330
	Gas	Electric	10.667	1.697	1.576	3	0.290	3.400
		Gas	7.750	1.102	0.525	4	0.410	1.600
Outdoor	Electric	Electric	.	0.427	0.349	3	0.220	0.830
	Gas	Electric	.	0.393	0.201	3	0.180	0.580
		Gas	.	0.442	0.329	4	0.140	0.830

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Chrysene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.930	0.360	3	0.580	1.300
	Gas	Electric	6.667	1.887	1.575	3	0.860	3.700
		Gas	4.250	1.500	0.115	4	1.400	1.600
Living Room	Electric	Electric	3.000	0.783	0.263	3	0.480	0.940
	Gas	Electric	10.667	3.450	3.351	3	0.750	7.200
		Gas	7.750	2.325	0.971	4	1.200	3.500
Outdoor	Electric	Electric	.	1.030	0.410	3	0.590	1.400
	Gas	Electric	.	1.340	0.750	3	0.820	2.200
		Gas	.	0.987	0.623	4	0.360	1.600

COMPOUND Benzofluoranthenes

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.763	0.215	3	0.580	1.000
	Gas	Electric	6.667	1.643	1.104	3	0.830	2.900
		Gas	4.250	1.500	0.216	4	1.200	1.700
Living Room	Electric	Electric	3.000	0.737	0.208	3	0.510	0.920
	Gas	Electric	10.667	2.813	2.244	3	0.740	5.100
		Gas	7.750	2.550	0.100	4	2.500	2.700
Outdoor	Electric	Electric	.	0.883	0.538	3	0.510	1.500
	Gas	Electric	.	1.137	0.456	3	0.610	1.400
		Gas	.	1.305	0.846	4	0.480	2.300

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Benzo(e)pyrene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	1.310	1.100	3	0.330	2.500
	Gas	Electric	6.667	1.980	2.189	3	0.550	4.500
		Gas	4.250	1.047	0.341	4	0.710	1.500
Living Room	Electric	Electric	3.000	0.850	0.394	3	0.570	1.300
	Gas	Electric	10.667	5.663	4.810	3	0.490	10.000
		Gas	7.750	2.375	1.261	4	1.200	3.700
Outdoor	Electric	Electric	.	0.393	0.214	3	0.260	0.640
	Gas	Electric	.	0.477	0.208	3	0.240	0.630
		Gas	.	0.517	0.320	4	0.210	0.880

COMPOUND Benzo(a)pyrene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.380	0.156	3	0.280	0.560
	Gas	Electric	6.667	0.723	0.760	3	0.250	1.600
		Gas	4.250	0.505	0.142	4	0.310	0.620
Living Room	Electric	Electric	3.000	0.313	0.025	3	0.290	0.340
	Gas	Electric	10.667	1.660	1.527	3	0.280	3.300
		Gas	7.750	1.025	0.334	4	0.670	1.400
Outdoor	Electric	Electric	.	0.190	0.036	3	0.150	0.220
	Gas	Electric	.	0.230	0.113	3	0.100	0.300
		Gas	.	0.280	0.192	4	0.130	0.540

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Indeno(1,2,3-c,d)pyrene

			CIGARETTE	RESPONSE				
LOCATION	FURNACE	COOKING	Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	0.333	0.021	3	0.310	0.350
	Gas	Electric	6.667	0.540	0.419	3	0.180	1.000
		Gas	4.250	0.562	0.152	4	0.400	0.740
Living Room	Electric	Electric	3.000	0.313	0.081	3	0.240	0.400
	Gas	Electric	10.667	1.150	0.737	3	0.350	1.800
		Gas	7.750	0.917	0.146	4	0.700	1.000
Outdoor	Electric	Electric	.	0.263	0.153	3	0.170	0.440
	Gas	Electric	.	0.350	0.165	3	0.160	0.460
		Gas	.	0.435	0.239	4	0.230	0.740

COMPOUND Benzo(g,h,i)perylene

			CIGARETTE	RESPONSE				
LOCATION	FURNACE	COOKING	Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	0.587	0.110	3	0.500	0.710
	Gas	Electric	6.667	0.817	0.523	3	0.390	1.400
		Gas	4.250	0.770	0.265	4	0.480	1.100
Living Room	Electric	Electric	3.000	0.413	0.095	3	0.320	0.510
	Gas	Electric	10.667	1.470	0.997	3	0.510	2.500
		Gas	7.750	1.210	0.375	4	0.740	1.600
Outdoor	Electric	Electric	.	0.320	0.123	3	0.230	0.460
	Gas	Electric	.	0.537	0.310	3	0.200	0.810
		Gas	.	0.640	0.361	4	0.280	1.100

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Coronene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.443	0.250	3	0.170	0.660
	Gas	Electric	6.667	0.677	0.639	3	0.190	1.400
		Gas	4.250	0.535	0.403	4	0.230	1.100
Living Room	Electric	Electric	3.000	0.297	0.042	3	0.250	0.330
	Gas	Electric	10.667	0.803	0.534	3	0.370	1.400
		Gas	7.750	0.627	0.144	4	0.460	0.810
Outdoor	Electric	Electric	.	0.150	0.044	3	0.100	0.180
	Gas	Electric	.	0.387	0.295	3	0.090	0.680
		Gas	.	0.407	0.148	4	0.260	0.590

COMPOUND Nicotine

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	1333.333	986.577	3	200.000	2000.000
	Gas	Electric	6.667	9781.667	13350.075	3	45.000	25000.000
		Gas	4.250	2852.750	3363.705	4	48.000	6800.000
Living Room	Electric	Electric	3.000	808.000	843.203	3	24.000	1700.000
	Gas	Electric	10.667	16423.333	24826.007	3	170.000	45000.000
		Gas	7.750	11032.250	13894.438	4	60.000	29000.000
Outdoor	Electric	Electric	.	5.933	1.620	3	4.900	7.800
	Gas	Electric	.	11.900	14.880	3	1.900	29.000
		Gas	.	10.825	2.831	4	7.400	14.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Quinoline

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	77.333	46.361	3	28.000	120.000
	Gas	Electric	6.667	276.167	326.549	3	8.500	640.000
		Gas	4.250	71.000	76.972	4	9.000	170.000
Living Room	Electric	Electric	3.000	63.333	35.726	3	23.000	91.000
	Gas	Electric	10.667	469.800	564.780	3	9.400	1100.000
		Gas	7.750	185.525	224.034	4	9.100	480.000
Outdoor	Electric	Electric	.	2.927	2.389	3	0.780	5.500
	Gas	Electric	.	3.567	0.929	3	2.500	4.200
		Gas	.	3.350	0.929	4	2.400	4.600

COMPOUND Isoquinoline

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	51.333	14.012	3	40.000	67.000
	Gas	Electric	6.667	147.000	171.520	3	12.000	340.000
		Gas	4.250	47.775	46.133	4	8.100	110.000
Living Room	Electric	Electric	3.000	35.000	1.000	3	34.000	36.000
	Gas	Electric	10.667	270.333	311.850	3	21.000	620.000
		Gas	7.750	118.750	133.929	4	16.000	300.000
Outdoor	Electric	Electric	.	6.267	3.235	3	4.300	10.000
	Gas	Electric	.	10.300	4.782	3	4.900	14.000
		Gas	.	10.675	4.911	4	5.100	17.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Fluorenone

LOCATION	FURNACE	COOKING	CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	7.267	0.987	3	6.600	8.400
	Gas	Electric	6.667	16.200	14.897	3	4.600	33.000
		Gas	4.250	9.500	5.323	4	3.000	16.000
Living Room	Electric	Electric	3.000	7.133	0.737	3	6.300	7.700
	Gas	Electric	10.667	18.867	18.672	3	4.600	40.000
		Gas	7.750	10.575	4.580	4	6.200	17.000
Outdoor	Electric	Electric	.	3.300	0.458	3	2.800	3.700
	Gas	Electric	.	5.467	3.239	3	3.400	9.200
		Gas	.	3.875	0.695	4	2.900	4.500

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Naphthalene dicarboxylic acid anhydride

LOCATION	FURNACE	COOKING	CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	1.867	0.153	3	1.700	2.000
	Gas	Electric	6.667	5.200	0.721	3	4.600	6.000
		Gas	4.250	4.325	0.574	4	3.600	5.000
Living Room	Electric	Electric	3.000	3.400	3.297	3	1.300	7.200
	Gas	Electric	10.667	4.667	1.361	3	3.600	6.200
		Gas	7.750	3.900	1.977	4	2.400	6.800
Outdoor	Electric	Electric	.	10.500	3.176	3	7.800	14.000
	Gas	Electric	.	9.233	0.862	3	8.300	10.000
		Gas	.	8.925	2.794	4	4.800	11.000

CONCENTRATIONS - nanograms/cubic meter

COMPOUND 9-Nitroanthracene isomer

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.313	0.095	3	0.220	0.410
	Gas	Electric	6.667	0.667	0.480	3	0.150	1.100
		Gas	4.250	0.380	0.049	4	0.320	0.440
Living Room	Electric	Electric	3.000	0.410	0.144	3	0.250	0.530
	Gas	Electric	10.667	0.687	0.422	3	0.200	0.950
		Gas	7.750	0.417	0.197	4	0.290	0.710
Outdoor	Electric	Electric	.	0.330	0.210	3	0.180	0.570
	Gas	Electric	.	0.403	0.176	3	0.200	0.510
		Gas	.	0.280	0.111	4	0.150	0.420

COMPOUND 9-Nitroanthracene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.067	0.037	3	0.043	0.110
	Gas	Electric	6.667	0.183	0.065	3	0.120	0.250
		Gas	4.250	0.517	0.534	4	0.120	1.300
Living Room	Electric	Electric	3.000	0.106	0.059	3	0.039	0.150
	Gas	Electric	10.667	0.192	0.119	3	0.085	0.320
		Gas	7.750	0.322	0.134	4	0.160	0.480
Outdoor	Electric	Electric	.	0.027	0.013	3	0.012	0.036
	Gas	Electric	.	0.071	0.037	3	0.029	0.100
		Gas	.	0.063	0.015	4	0.051	0.086

CONCENTRATIONS - nanograms/cubic meter

COMPOUND 9-Nitrophenanthrene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.020	0.006	3	0.014	0.024
	Gas	Electric	6.667	0.088	0.089	3	0.035	0.190
		Gas	4.250	0.036	0.017	4	0.021	0.058
Living Room	Electric	Electric	3.000	0.028	0.018	3	0.008	0.043
	Gas	Electric	10.667	0.124	0.113	3	0.031	0.250
		Gas	7.750	0.047	0.037	4	0.020	0.100
Outdoor	Electric	Electric	.	0.023	0.018	3	0.003	0.039
	Gas	Electric	.	0.019	0.012	3	0.010	0.033
		Gas	.	0.017	0.009	4	0.005	0.027

COMPOUND Pyrene carboxaldehyde

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.064	0.045	3	0.021	0.110
	Gas	Electric	6.667	0.216	0.150	3	0.049	0.340
		Gas	4.250	0.071	0.048	4	0.028	0.140
Living Room	Electric	Electric	3.000	0.054	0.041	3	0.023	0.100
	Gas	Electric	10.667	0.152	0.157	3	0.035	0.330
		Gas	7.750	0.146	0.132	4	0.023	0.300
Outdoor	Electric	Electric	.	0.067	0.055	3	0.035	0.130
	Gas	Electric	.	0.069	0.045	3	0.035	0.120
		Gas	.	0.058	0.038	4	0.019	0.100

CONCENTRATIONS - nanograms/cubic meter

COMPOUND 2-Nitrofluoranthene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.020	0.011	3	0.009	0.030
	Gas	Electric	6.667	0.102	0.051	3	0.066	0.160
		Gas	4.250	0.037	0.009	4	0.031	0.049
Living Room	Electric	Electric	3.000	0.015	0.006	3	0.009	0.020
	Gas	Electric	10.667	0.074	0.057	3	0.041	0.140
		Gas	7.750	0.048	0.026	4	0.017	0.071
Outdoor	Electric	Electric	.	0.035	0.012	3	0.021	0.042
	Gas	Electric	.	0.086	0.030	3	0.064	0.120
		Gas	.	0.053	0.025	4	0.027	0.077

COMPOUND 1-Nitropyrene

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.029	0.018	3	0.019	0.050
	Gas	Electric	6.667	0.076	0.048	3	0.039	0.130
		Gas	4.250	0.028	0.006	4	0.020	0.034
Living Room	Electric	Electric	3.000	0.292	0.466	3	0.021	0.830
	Gas	Electric	10.667	0.072	0.050	3	0.021	0.120
		Gas	7.750	0.045	0.020	4	0.021	0.063
Outdoor	Electric	Electric	.	0.020	0.003	3	0.017	0.023
	Gas	Electric	.	0.030	0.007	3	0.022	0.036
		Gas	.	0.018	0.004	4	0.012	0.021

CONCENTRATIONS - nanograms/cubic meter

COMPOUND Benz(a)anthracene-7,12-dione

			CIGARETTE	RESPONSE				
LOCATION	FURNACE	COOKING	Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	0.206	0.108	3	0.088	0.300
	Gas	Electric	6.667	0.480	0.271	3	0.200	0.740
		Gas	4.250	0.347	0.120	4	0.170	0.430
Living Room	Electric	Electric	3.000	0.207	0.078	3	0.120	0.270
	Gas	Electric	10.667	0.417	0.367	3	0.180	0.840
		Gas	7.750	0.587	0.190	4	0.320	0.750
Outdoor	Electric	Electric	.	0.200	0.079	3	0.140	0.290
	Gas	Electric	.	0.257	0.110	3	0.150	0.370
		Gas	.	0.212	0.090	4	0.110	0.310

COMPOUND Pyrene-3,4-dicarboxylic acid anhydride

			CIGARETTE	RESPONSE				
LOCATION	FURNACE	COOKING	Mean	Mean	Standard Deviation	n	Minimum	Maximum
Kitchen	Electric	Electric	3.333	0.074	0.022	3	0.051	0.095
	Gas	Electric	6.667	0.220	0.128	3	0.079	0.330
		Gas	4.250	0.270	0.133	4	0.130	0.440
Living Room	Electric	Electric	3.000	0.059	0.023	3	0.036	0.081
	Gas	Electric	10.667	0.155	0.064	3	0.085	0.210
		Gas	7.750	0.180	0.088	4	0.100	0.270
Outdoor	Electric	Electric	.	0.297	0.185	3	0.190	0.510
	Gas	Electric	.	0.197	0.076	3	0.110	0.250
		Gas	.	0.380	0.216	4	0.100	0.560

CONCENTRATIONS - milligrams/cubic meter

COMPOUND Total Extractable Organic Mass

			CIGARETTE	RESPONSE				
			Mean	Mean	Standard Deviation	n	Minimum	Maximum
LOCATION	FURNACE	COOKING						
Kitchen	Electric	Electric	3.333	0.110	0.027	3	0.079	0.130
	Gas	Electric	6.667	0.212	0.171	3	0.066	0.400
		Gas	4.250	0.177	0.078	4	0.120	0.290
Living Room	Electric	Electric	3.000	0.112	0.037	3	0.077	0.150
	Gas	Electric	10.667	0.305	0.254	3	0.064	0.570
		Gas	7.750	0.185	0.066	4	0.130	0.280
Outdoor	Electric	Electric	.	0.016	0.007	3	0.011	0.024
	Gas	Electric	.	0.027	0.017	3	0.016	0.047
		Gas	.	0.013	0.004	4	0.009	0.018

APPENDIX D

Summary of the Modeling Results For All Target Compounds

TABLE D.1 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR NAPHTHALENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level (a)
HS (Heating System)	419	320	1.31	.19
ST (Cooking Appliances)	-467	243	-1.92	.06
β_1 (Cigarettes Smoked)	35	31	1.12	.26
L (Location)	157	135	1.16	.24
β_2 (Air Exchanges Per Hour)	-566	384	-1.48	.14

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	431
D (Day-to-day variability)	0(b)
E (Variability due to other factors)	578

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.2 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR ACENAPHTHYLENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level (a)
HS (Heating System)	15.7	5.2	3.03	< .01
ST (Cooking Appliances)	-12.8	4.2	-3.04	< .01
β_1 (Cigarettes Smoked)	3.2	0.5	6.18	< .01
L (Location)	1.3	2.0	0.7	.50
β_2 (Air Exchanges Per Hour)	-13.9	6.5	-2.16	.03

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0(b)
D (Day-to-day variability)	8.6
E (Variability due to other factors)	8.4

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.3 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR PHENANTHRENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Significance Level [a]
HS (Heating System)	14.4	24.1	0.60	.55
ST (Cooking Appliances)	6.3	18.2	0.35	.73
β_1 (Cigarettes Smoked)	4.8	1.5	3.10	< .01
L (Location)	-0.04	4.5	0.01	.99
β_2 (Air Exchanges Per Hour)	-21.2	27.4	-0.78	.44

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	42.4
D (Day-to-day variability)	0[b]
E (Variability due to other factors)	18.1

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.4 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR ANTHRACENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level (a)
HS (Heating System)	0.08	1.07	0.07	.94
ST (Cooking Appliances)	0.25	0.80	0.31	.76
β_1 (Cigarettes Smoked)	0.55	0.09	6.20	< .01
L (Location)	0.20	0.31	0.63	.53
β_2 (Air Exchanges Per Hour)	0.48	1.26	0.38	.70

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	1.73
D (Day-to-day variability)	0(b)
E (Variability due to other factors)	1.28

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.5 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR FLUORANTHENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level (a)
HS (Heating System)	2.8	2.9	0.95	.34
ST (Cooking Appliances)	1.1	2.2	0.52	.60
β_1 (Cigarettes Smoked)	0.4	0.2	1.62	.11
L (Location)	-0.5	0.7	-0.69	.49
β_2 (Air Exchanges Per Hour)	-4.2	3.4	-1.22	.22

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	4.7
D (Day-to-day variability)	1.2
E (Variability due to other factors)	3.1

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.6 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR PYRENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level (a)
HS (Heating System)	3.0	1.4	2.11	.04
ST (Cooking Appliances)	-0.5	1.1	-0.45	.65
β_1 (Cigarettes Smoked)	0.2	0.1	1.80	.07
L (Location)	-0.05	0.5	-0.09	.93
β_2 (Air Exchanges Per Hour)	-3.6	1.7	-2.12	.03

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	2.0
D (Day-to-day variability)	1.0
E (Variability due to other factors)	2.1

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D-7. ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR CYCLOPENTA[C,D]PYRENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	 Significance Level (a)
HS (Heating System)	0.18	0.16	1.09	.28
ST (Cooking Appliances)	-0.11	0.13	-0.91	.36
β_1 (Cigarettes Smoked)	0.07	0.01	5.27	< .01
L (Location)	0.04	0.04	1.09	.28
β_2 (Air Exchanges Per Hour)	-0.18	0.20	-0.90	.37

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.19
D (Day-to-day variability)	0.22
E (Variability due to other factors)	0.14

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.8 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR BENZ[A]ANTHRACENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Significance Level [a]
HS (Heating System)	0.31	0.25	1.22	.22
ST (Cooking Appliances)	-0.15	0.19	-0.79	.43
β_1 (Cigarettes Smoked)	0.10	0.02	4.51	< .01
L (Location)	0.12	0.07	1.62	.11
β_2 (Air Exchanges Per Hour)	-0.29	0.30	-0.95	.34

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.35
D (Day-to-day variability)	0.23
E (Variability due to other factors)	0.29

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.9 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR CHRYSENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level (a)
HS (Heating System)	0.56	0.60	0.92	.36
ST (Cooking Appliances)	-0.30	0.46	-0.65	.52
β_1 (Cigarettes Smoked)	0.20	0.04	4.60	< .01
L (Location)	0.13	0.13	0.98	.33
β_2 (Air Exchanges Per Hour)	-0.61	0.72	0.86	.39

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.99
D (Day-to-day variability)	0.32
E (Variability due to other factors)	0.53

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.10 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR BENZOFLUORANTHENES

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	 Significance Level [a]
HS (Heating System)	0.56	0.44	1.28	.20
ST (Cooking Appliances)	-0.05	0.33	-0.16	.87
β_1 (Cigarettes Smoked)	0.11	0.03	3.42	< .01
L (Location)	0.22	0.10	2.17	.03
β_2 (Air Exchanges Per Hour)	-0.49	0.51	-0.96	.34

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.75
D (Day-to-day variability)	0[b]
E (Variability due to other factors)	0.41

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.11 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR BENZO[E]PYRENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level [(a)]
HS (Heating System)	1.22	0.43	2.85	< .01
ST (Cooking Appliances)	-0.96	0.35	-2.78	< .01
β_1 (Cigarettes Smoked)	0.27	0.05	5.86	< .01
L (Location)	0.41	0.28	1.47	.14
β_2 (Air Exchanges Per Hour)	-1.42	0.53	-2.68	< .01

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0(b)
D (Day-to-day variability)	0
E (Variability due to other factors)	1.21

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.12 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR BENZO[A]PYRENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level [(a)]
HS (Heating System)	0.32	0.25	1.28	.20
ST (Cooking Appliances)	-0.18	0.18	-0.98	.33
β_1 (Cigarettes Smoked)	0.08	0.02	3.85	< .01
L (Location)	0.14	0.07	1.87	.06
β_2 (Air Exchanges Per Hour)	-0.31	0.29	-1.08	.28

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.39
D (Day-to-day variability)	0(b)
E (Variability due to other factors)	0.30

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.13 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR INDENO[1,2,3-c,d]PYRENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level [a]
HS (Heating System)	0.24	0.09	2.74	< .01
ST (Cooking Appliances)	-0.04	0.07	0.57	.57
β_1 (Cigarettes Smoked)	0.04	0.01	3.84	< .01
L (Location)	0.11	0.06	2.00	.05
β_2 (Air Exchanges Per Hour)	-0.20	0.11	-1.79	.07

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0[b]
D (Day-to-day variability)	0
E (Variability due to other factors)	0.25

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.14 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR BENZO[G,H,I]PERYLENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level [(a)]
HS (Heating System)	0.20	0.16	1.25	.21
ST (Cooking Appliances)	-0.03	0.13	-0.20	.84
β_1 (Cigarettes Smoked)	0.06	0.02	3.90	< .01
L (Location)	0.08	0.06	1.33	.18
β_2 (Air Exchanges Per Hour)	-0.14	0.20	-0.70	.49

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.20
D (Day-to-day variability)	0.15
E (Variability due to other factors)	0.27

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.15 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR CORONENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level (a)
HS (Heating System)	0.17	0.13	1.28	.20
ST (Cooking Appliances)	-0.07	0.11	-0.66	.51
β_1 (Cigarettes Smoked)	0.02	0.01	1.22	.22
L (Location)	-0.01	0.09	0.07	.94
β_2 (Air Exchanges Per Hour)	-0.07	0.16	-0.44	.66

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0(b)
D (Day-to-day variability)	0
E (Variability due to other factors)	0.37

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.16 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR NICOTINE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Significance Level [(a)]
HS (Heating System)	1497	5007	0.30	.77
ST (Cooking Appliances)	-1409	3820	-0.37	.71
β_1 (Cigarettes Smoked)	1681	333	5.05	< .01
L (Location)	452	925	0.49	.63
β_2 (Air Exchanges Per Hour)	-1274	6038	-0.21	.83

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	7989
D (Day-to-day variability)	4012
E (Variability due to other factors)	3696

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.17 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR QUINOLINE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level [(a)]
HS (Heating System)	107	87	1.24	.22
ST (Cooking Appliances)	-102	69	-1.48	.14
β_1 (Cigarettes Smoked)	34	5	6.44	< .01
L (Location)	7	14	0.50	.62
β_2 (Air Exchanges Per Hour)	-128	108	-1.18	.24

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	97
D (Day-to-day variability)	133
E (Variability due to other factors)	55

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.18 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR ISOQUINOLINE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level [(a)]
HS (Heating System)	47	56	0.84	.40
ST (Cooking Appliances)	-49	43	-1.14	.26
β_1 (Cigarettes Smoked)	20	3	5.71	< .01
L (Location)	5	9	0.60	.55
β_2 (Air Exchanges Per Hour)	-58	69	-0.85	.40

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	80
D (Day-to-day variability)	64
E (Variability due to other factors)	36

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.19 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR FLUORENONE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance: z-value	Tests of Significance: Significance Level (a)
HS (Heating System)	5.3	4.4	1.20	.23
ST (Cooking Appliances)	-3.7	3.4	-1.10	.27
β_1 (Cigarettes Smoked)	0.6	0.2	3.60	< .01
L (Location)	-0.2	0.4	-0.43	.66
β_2 (Air Exchanges Per Hour)	-4.9	5.2	-0.94	.35

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	7.8
D (Day-to-day variability)	2.5
E (Variability due to other factors)	1.6

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.20 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR NAPHTHALENE DICARBOXYLIC ACID ANHYDRIDE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level [(a)]
HS (Heating System)	0.73	0.88	0.83	.40
ST (Cooking Appliances)	-0.25	0.66	-0.39	.70
β_1 (Cigarettes Smoked)	0.06	0.08	0.67	.50
L (Location)	-0.004	0.33	-0.01	.99
β_2 (Air Exchanges Per Hour)	0.21	1.05	0.20	.84

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	1.27
D (Day-to-day variability)	0[(b)]
E (Variability due to other factors)	1.40

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.21 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR 9-NITROANTHRACENE ISOMER

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance: z-value	Tests of Significance: Significance Level (a)
HS (Heating System)	0.18	0.04	4.26	< .01
ST (Cooking Appliances)	-0.15	0.03	-4.29	< .01
β_1 (Cigarettes Smoked)	0.03	0.01	6.38	< .01
L (Location)	-0.01	0.03	-0.44	.66
β_2 (Air Exchanges Per Hour)	-0.25	0.05	-4.69	< .01

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0 (b)
D (Day-to-day variability)	0
E (Variability due to other factors)	0.12

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.22 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR 9-NITROANTHRACENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level (a)
HS (Heating System)	0.08	0.10	0.84	.40
ST (Cooking Appliances)	0.10	0.08	1.27	.21
β_1 (Cigarettes Smoked)	0.003	0.01	0.31	.75
L (Location)	-0.04	0.06	-0.63	.53
β_2 (Air Exchanges Per Hour)	-0.10	0.12	-0.81	.42

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0(b)
D (Day-to-day variability)	0.09
E (Variability due to other factors)	0.25

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.23 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR 9-NITROPHENANTHRENE

Fixed Effects Factors

			Tests of Significance	
Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	z-value	Significance Level (a)
HS (Heating System)	0.031	0.027	1.18	.24
ST (Cooking Appliances)	-0.030	0.020	-1.49	.14
β_1 (Cigarettes Smoked)	0.005	0.002	3.36	$< .01$
L (Location)	0.002	0.004	0.53	.60
β_2 (Air Exchanges Per Hour)	-0.018	0.031	-0.58	.57

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.045
D (Day-to-day variability)	0 (b)
E (Variability due to other factors)	0

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.24 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR PYRENE CARBOXALDEHYDE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level [(a)]
HS (Heating System)	0.031	0.022	1.44	.15
ST (Cooking Appliances)	-0.022	0.017	-1.27	.20
β_1 (Cigarettes Smoked)	0.014	0.002	5.84	$< .01$
L (Location)	-0.014	0.014	-0.99	.32
β_2 (Air Exchanges Per Hour)	-0.015	0.027	-0.57	.57

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0(b)
D (Day-to-day variability)	0
E (Variability due to other factors)	0.063

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.25 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR 2-NITROFLUORANTHENE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Tests of Significance Significance Level (a)
HS (Heating System)	0.031	0.015	2.08	.04
ST (Cooking Appliances)	-0.021	0.011	1.87	.06
β_1 (Cigarettes Smoked)	0.003	0.001	2.23	.03
L (Location)	-0.006	0.004	1.56	.12
β_2 (Air Exchanges Per Hour)	-0.010	0.018	-0.55	.59

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.032
D (Day-to-day variability)	0(b)
E (Variability due to other factors)	0

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.26 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR 1-NITROPYRENE[a]

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Significance Level [b]
HS (Heating System)	0.023	0.009	2.62	< .01
ST (Cooking Appliances)	-0.018	0.007	-2.48	.01
β_1 (Cigarettes Smoked)	0.003	0.001	3.77	< .01
L (Location)	-0.003	0.003	-0.86	.39
β_2 (Air Exchanges Per Hour)	-0.017	0.011	-1.57	.12

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0[c]
D (Day-to-day variability)	0
E (Variability due to other factors)	0

(a) These results do not include one measured outlier value of 0.83 ng/m^3.

(b) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(c) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.27 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR BENZ[A]ANTHRACENE-7,12-DIONE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance	
			z-value	Significance Level (a)
HS (Heating System)	0.13	0.07	1.80	.07
ST (Cooking Appliances)	0.01	0.06	0.11	.91
β_1 (Cigarettes Smoked)	0.02	0.01	2.62	< .01
L (Location)	0.01	0.03	0.43	.67
β_2 (Air Exchanges Per Hour)	-0.15	0.09	-1.67	.10

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.04
D (Day-to-day variability)	0.09
E (Variability due to other factors)	0.14

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

TABLE D.28 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR PYRENE-3,4-DICARBOXYLIC ACID ANHYDRIDE

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (ng/m^3)	Standard Error of Coefficient (ng/m^3)	Tests of Significance z-value	Significance Level [(a)]
HS (Heating System)	0.007	0.029	0.24	.81
ST (Cooking Appliances)	0.044	0.022	1.99	.05
β_1 (Cigarettes Smoked)	0.002	0.003	0.66	.51
L (Location)	-0.032	0.010	-3.10	< .01
β_2 (Air Exchanges Per Hour)	0.113	0.035	3.27	< .01

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (ng/m^3)
H (Home-to-home variability)	0.032
D (Day-to-day variability)	0[(b)]
E (Variability due to other factors)	0.045

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

(b) A value of zero for the square root of an estimated variance implies that that source of variability made a negligible contribution to the overall variance when compared to variability due to the other factors.

TABLE D.29 ESTIMATED MODEL COEFFICIENTS AND OTHER MODELING RESULTS FOR TOTAL EXTRACTABLE ORGANIC MASS

Fixed Effects Factors

Model Coefficients	Estimated Coefficient (mg/m^3)	Standard Error of Coefficient (mg/m^3)	Tests of Significance	
			z-value	Significance Level [(a)]
HS (Heating System)	0.082	0.038	2.16	.03
ST (Cooking Appliances)	-0.043	0.030	-1.45	.15
β_1 (Cigarettes Smoked)	0.013	0.004	3.65	< .01
L (Location)	0	0.013	0.04	.97
β_2 (Air Exchanges Per Hour)	-0.111	0.047	-2.39	.02

Random Effects Factors

Model Coefficients	Square Root of Estimated Variance (mg/m^3)
H (Home-to-home variability)	0.045
D (Day-to-day variability)	0.045
E (Variability due to other factors)	0.055

(a) The significance level is the probability that the estimated coefficient (or a larger value) could have occurred when the corresponding experimental factor actually had no effect on concentration level. Thus, a small significance level (e.g. less than .10) indicates the factor likely had an effect on concentration level.

APPENDIX E

Least-Squares Regression Equations for Predicting Target Compound Levels from Levels of Potential Marker Compounds

TABLE E.1 LEAST-SQUARE REGRESSION EQUATIONS FOR PREDICTING TARGET COMPOUND LEVELS(a) FROM FLUORANTHENE LEVELS

Target Compound	Intercept of Regression Equation	Slope of Regression Equation	R-SQUARE Value (Percent)
Naphthalene	501.5	51.5	10
Acenaphthylene	-3.97	2.73	36
Anthracene	-0.27	0.43	40
Cyclopenta[c,d]pyrene	-0.08	0.05	35
Benz[a]anthracene	-0.0043	0.073	35
Chrysene	0.053	0.17	45
Benzofluoranthenes	0.37	0.12	44
Benzo[e]pyrene	-0.29	0.20	27
Benzo[a]pyrene	-0.094	0.074	38
Indeno[1,2,3-c,d]pyrene	0.17	0.04	35
Benzo[g,h,i]perylene	0.22	0.059	40
Coronene	0.29	0.021	12
Nicotine	-6126	1176	37
Quinoline	-113.2	25.8	34
Isoquinoline	-59.8	14.7	37
Fluorenone	-1.11	1.10	51
Naphthalene dicarboxylic acid anhydride	6.93	-0.13	4
9-nitroanthracene isomer	0.25	0.019	17
9-nitroanthracene	-0.10	0.031	48
9-nitrophenanthrene	-0.0043	0.0052	28
Pyrene carboxaldehyde	0.040	0.0063	14
2-nitrofluoranthene	0.033	0.0020	9
1-nitropyrene	0.058	0.00062	0
Benz[a]anthracene-7, 12-dione	0.11	0.024	41
Pyrene-3, 4-dicarboxylic acid anhydride	0.23	-0.0022	1
Total Extractable Organic Mass(b)	-0.036	0.018	56

(a) Concentration units are in ng/m^3.

(b) Concentration units are in mg/m^3.

TABLE E.2 LEAST-SQUARE REGRESSION EQUATIONS FOR PREDICTING TARGET COMPOUND LEVELS(a) FROM PYRENE LEVELS

Target Compound	Intercept of Regression Equation	Slope of Regression Equation	R-SQUARE Value (Percent)
Naphthalene	205.8	121.1	25
Acenaphthylene	-11.0	5.1	53
Anthracene	-0.58	0.67	43
Cyclopenta[c,d]pyrene	-0.20	0.089	53
Benz[a]anthracene	-0.18	0.13	51
Chrysene	-0.31	0.30	64
Benzofluoranthenes	0.19	0.20	53
Benzo[e]pyrene	-1.01	0.41	47
Benzo[a]pyrene	-0.25	0.13	54
Indeno[1,2,3-c,d]pyrene	0.07	0.08	51
Benzo[g,h,i]perylene	0.11	0.10	53
Coronene	0.18	0.048	26
Nicotine	-7438.9	1907.9	43
Quinoline	-167.9	45.9	48
Isoquinoline	-88.1	25.8	49
Fluorenone	-2.92	1.88	65
Naphthalene dicarboxylic acid anhydride	6.37	-0.093	1
9-nitroanthracene isomer	0.15	0.043	40
9-nitroanthracene	-0.066	0.40	34
9-nitrophenanthrene	-0.020	0.010	46
Pyrene carboxaldehyde	0.022	0.012	21
2-nitrofluoranthene	0.025	0.0043	17
1-nitropyrene	0.042	0.0035	1
Benz[a]anthracene-7, 12-dione	0.09	0.038	43
Pyrene-3, 4-dicarboxylic acid anhydride	0.23	-0.0032	1
Total Extractable Organic Mass(b)	-0.062	0.03	70

(a) Concentration units are in ng/m^3.

(b) Concentration units are in mg/m^3.

TABLE E.3 LEAST-SQUARE REGRESSION EQUATIONS FOR PREDICTING TARGET COMPOUND LEVELS(a) FROM PHENANTHRENE LEVELS

Target Compound	Intercept of Regression Equation	Slope of Regression Equation	R-SQUARE Value (Percent)
Naphthalene	225.6	9.58	32
Acenaphthylene	-0.14	0.37	59
Anthracene	-0.97	0.06	67
Cyclopenta[c,d]pyrene	-0.12	0.01	51
Benz[a]anthracene	-0.03	0.01	46
Chrysene	0.09	0.02	52
Benzofluoranthenes	0.48	0.01	43
Benzo[e]pyrene	-0.71	0.03	49
Benzo[a]pyrene	-0.16	0.01	56
Indeno[1,2,3-c,d]pyrene	0.14	0.01	50
Benzo[g,h,i]perylene	0.19	0.01	55
Coronene	0.23	0.003	24
Nicotine	-7076.78	150.39	54
Quinoline	-146.9	3.46	55
Isoquinoline	-76.8	1.95	57
Fluorenone	-1.24	0.13	63
Naphthalene dicarboxylic acid anhydride	7.75	-0.03	15
9-nitroanthracene isomer	0.21	0.002	33
9-nitroanthracene	-0.01	0.002	27
9-nitrophenanthrene	-0.01	0.001	36
Pyrene carboxaldehyde	0.03	0.001	24
2-nitrofluoranthene	0.04	0.0002	8
1-nitropyrene	0.05	0.0001	0
Benz[a]anthracene-7, 12-dione	0.13	0.003	40
Pyrene-3, 4-dicarboxylic acid anhydride	0.26	-0.001	5
Total Extractable Organic Mass(b)	-0.04	0.002	71

(a) Concentration units are in ng/m^3.

(b) Concentration units are in mg/m^3.

APPENDIX F

The Target Compound Concentrations Found in the Field Blank Samples

TABLE F-1 TARGET COMPOUND CONCENTRATIONS FOUND IN THE FIELD BLANKS

Compound	Normalized Concentration, ng/m^3 [(a)]	
	Indoor-BLK	Outdoor-BLK
Naphthalene	3.5	1.4
Acenaphthylene	ND[(b)]	ND
Phenanthrene	0.15	0.12
Anthracene	ND	ND
Fluoranthene	0.038	0.035
Pyrene	0.028	0.019
Cyclopenta[c,d]pyrene	ND	ND
Benz[a]anthracene	0.002	0.002
Chrysene	0.006	0.002
Benzofluoranthenes	0.003	<0.001
Benzo[e]pyrene	0.004	ND
Benzo[a]pyrene	ND	ND
Indeno[1,2,3-c,d]pyrene	ND	ND
Benzo[g,h,i]perylene	ND	ND
Cordnene	ND	ND
Nicotine	1.2	0.42
Quinoline	0.065	0.012
Isoquinoline	0.075	0.028
Fluorenone	0.61	0.20
Naphthalene-1,8-dicarboxylic acid anhydride	0.44	0.20
9-nitroanthracene isomer	0.012	0.011
9-nitroanthracene	ND	ND
Pyrene carboxaldehyde	ND	ND
2-Nitrofluoranthene	ND	ND
1-Nitropyrene	ND	ND
Benz[a]anthracene-7,12-dione	ND	ND
Pyrene-3,4-dicarboxylic acid anhydride	ND	ND

(a) The sample volumes for indoor and outdoor blanks were assumed to be 100 m^3 and 200 m^3, respectively.

(b) Not detected.

APPENDIX G

The Particulate Weights of the Filter Samples

TABLE G-1 THE PARTICULATE WEIGHTS OF THE FILTER SAMPLES

	Particulate Weights, mg (mg/m^3)		
Home Code	Kitchen	Living Room	Outdoor
1	2.4(a) (0.022)	3.5 (0.034)	5.4 (0.025)
2	17 (0.16)	14 (0.14)	9.1 (0.042)
3	8.2 (0.070)	8.6 (0.097)	7.1 (0.032)
3 (2)	4.6 (0.042)	2.1(a) (0.021)	7.8 (0.036)
4	8.8(a) (0.081)	12 (0.14)	21 (0.10)
5	17 (0.16)	17 (0.16)	8.4 (0.040)
6	13(a) (0.089)	23 (0.26)	9.9 (0.040)
7	3.9(a) (0.032)	7.9 (0.091)	7.2 (0.033)
8	17 (0.15)	6.2 (0.063)	4.9 (0.023
8 (2)	8.3 (0.074)	8.4 (0.080)	9.1 (0.042)

(a) The edges of these filter samples were broken after sampling, therefore these particulate weights are underestimated.